Appendix A.

Review of Modeling and Emission Inventory Development for the Regional Haze Implementation Plan for the State of Arkansas

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Chapter 1: Background and Introduction

1.1 BACKGROUND

Regional haze is visibility impairment that is caused overwhelmingly by fine particulates (PM2.5). Visibility impairment occurs when PM2.5 in the atmosphere scatters and absorbs light, thereby creating haze. PM2.5 can be emitted into the atmosphere directly as primary particulates, or it can be produced in the atmosphere from photochemical reactions of gas-phase precursors and subsequent condensation to form secondary particulates. Examples of primary PM2.5 include crustal materials and elemental carbon; examples of secondary PM include ammonium nitrate, ammonium sulfates, and secondary organic aerosols (SOA). Secondary PM2.5 is generally smaller than primary PM2.5, and because the ability of PM2.5 to scatter light depends on particle size, with light scattering for fine particles being greater than for coarse particles, secondary PM2.5 plays an especially important role in visibility impairment. Moreover, the smaller secondary PM2.5 can remain suspended in the atmosphere for longer periods and is transported long distances, thereby contributing to regional-scale impacts of pollutant emissions on visibility.

The sources of PM2.5 are difficult to quantify because of the complex nature of their formation, transport, and removal from the atmosphere. This makes it difficult to simply use emissions data to determine which pollutants should be controlled to most effectively improve visibility. Photochemical air quality models offer opportunity to better understand the sources of PM2.5 by simulating the emissions of pollutants and the formation, transport, and deposition of PM2.5. If an air quality model performs well for a historical episode, the model may then be useful for identifying the sources of PM2.5 and helping to select the most effective emissions reduction strategies for attaining visibility goals. Although several types of air quality modeling systems are available, the gridded, three-dimensional, Eulerian models provide the most complete spatial representation and the most comprehensive representation of processes affecting PM2.5, especially for situations in which multiple pollutant sources interact to form PM2.5.

In Section 169A of the 1977 Amendments to CAA, Congress set forth a program for protecting visibility in the nation's national parks and wilderness areas. This section of the CAA establishes as a national goal the "prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Federal Class I areas which impairment results from manmade air pollution." EPA promulgated a rule to address regional haze on July 1, 1999 (64 FR 35713), the Regional Haze Rule (RHR). The RHR established the goal of achieving "natural" visibility conditions in all 156 Federal Class I areas by 2064.

Because the pollutants that lead to regional haze can originate from sources located across broad geographic areas, EPA has encouraged the States and Tribes across the United States to address visibility impairment from a regional perspective. Five Regional Planning Organizations (RPOs) were developed to address regional haze and related issues (Figure 1-1). One of the main objectives of the RPOs is to analyze available data and conduct pollutant transport modeling to assist the States in developing their regional haze plans.

Figure 1-1. Map of Regional Planning Organizations

The Central Regional Air Planning Association (CENRAP) RPO is a collaborative effort of State governments, tribal governments, and various federal agencies established to conduct data analyses, conduct pollutant transport modeling, and coordinate planning activities among the central States. CENRAP members include the State governments of Nebraska, Kansas, Oklahoma, Texas, Minnesota, Iowa, Missouri, Arkansas, and Louisiana and Tribal governments included in these states.

1.2 TECHNICAL REQUIREMENTS FOR REGIONAL HAZE SIPS

The RHR does not mandate specific milestones or rates of progress, but instead calls for States to establish goals that provide for "reasonable progress" toward achieving natural visibility conditions. In setting Reasonable Progress Goals (RPGs), States must provide for an improvement in visibility for the most impaired days over the ten-year period of the SIP, and ensure no degradation in visibility for the least impaired days over the same period. In setting the RPGs for each 10-year period covered by a SIP, States must also compare the RPGs to the uniform rate of progress needed to reach natural visibility conditions by 2064, referred to as the "glide path", which is the linear rate of reduction in visibility impairment (in deciviews) needed to achieve natural conditions by 2064.

According to the RHR, Regional Haze SIPs must specifically identify and address the following elements:

i. Baseline Visibility Conditions
ii. Natural Visibility Conditions
iii. Uniform Rate of Progress
iv. Best Available Retrofit Technology (BART)
v. Current and Future (2018) Emission Inventories
vi. Source Contribution to Haze
vii. Reasonable Progress Goals

The purpose of this document is to review the technical products developed by the Arkansas Department of Environmental Quality (ADEQ) and CENRAP for the central regional states, in support of their RH SIP. This document evaluated the methods and procedures used by ADEQ and CENRAP to develop the modeling and emission inventory products that assisted Arkansas and the central regional States in addressing the required elements of a RH SIP. Specifically, this document reviewed emission inventory, meteorological, photochemical, and BART modeling conducted by CENRAP, evaluated the results and determined if these models met applicable guidelines or protocols, and met modeling standards at the time they were conducted.

Chapter 2: Development of Baseline and Natural Visibility Conditions and Glidepath

2.1 INTRODUCTION

Under the Regional Haze Rule (RHR), each State is required to demonstrate reasonable progress in visibility conditions for each of its Class I areas. The State is to determine a uniform rate of progress ("glide path", "glide slope") toward the goal of natural visibility conditions in 2064. Considering various statutory factors, the State is also to define a reasonable rate of progress, and compare this to the benchmark uniform rate; if projected progress is less than the uniform rate, then the State is to explain why. Procedures for assessing progress are described in the Regional Haze Rule and EPA guidance documents.

In brief, the guidance defines a metric to quantify visibility conditions, together with procedures for determining a starting point and an ending point, between which progress is to be made. The metric used is the Haze Index, measured in deciviews, and is designed to correspond to human perception of visibility changes. It is defined as:

$$10*ln(b_{ext}/10) \qquad (1)$$

where b_{ext} is extinction, the fraction of light scattered out of a sight path due to pollutants over a given distance (with units of Mm^{-1} or "inverse megameters"); it is inversely related to visual range. A 24-hour average is used, so there is a deciview value for each day of the year; the average of the 20% most-impaired days, and the average of the 20% least-impaired days during a year are to be assessed. The Regional Haze Rule goal is to improve visibility on the worst 20% of days, while having no degradation on the best 20%.

The starting point for progress is current or baseline visibility conditions, as monitored by the Interagency Monitoring of PROtected Visual Environments (IMPROVE) monitoring network (webpage and data access: http://vista.cira.colostate.edu/improve/Default.htm). 24-hour samples are collected every three days and are sent to a laboratory facility for analysis to obtain dry concentrations of a wide variety of species that impact visibility. Monitored pollutant concentrations are converted to visibility extinction using the IMPROVE equation, which adds up the contribution of each pollutant to extinction, while accounting for the effect of relative humidity. This total extinction is then converted to deciviews in the Haze Index through equation 1. For each of the years of the baseline period (2000-2004), the average of the deciviews on the worst 20% of days is calculated; the five-year average of these defines the baseline. This procedure is described in detail in EPA's "Guidance for Tracking Progress Under the Regional Haze Rule".[1] The guidance also makes provisions for dealing with missing data, since monitoring instrument maintenance and malfunctions mean that data is not available for every scheduled measurement.

The end point for progress is the goal of natural visibility conditions in 2064. The default approach for determining these is described in EPA's "Guidance for Estimating Natural Visibility

[1] Hereafter "GTR": EPA, 2003, *Guidance for Tracking Progress Under the Regional Haze Rule*, EPA-454/B-03-004, September 2003, EPA OAQPS ; web page: http://www.epa.gov/ttn/oarpg/t1pgm.html
direct link: http://www.epa.gov/ttn/oarpg/t1/memoranda/rh_tpurhr_gd.pdf

Conditions Under the Regional Haze Program".[2] Annual average natural background pollutant concentrations are estimated by Trijonis et al.[3] under NAPAP for the East and West parts of the country. Deciviews are calculated based on these natural background estimates with the IMPROVE equation, using the monthly relative humidity for each specific Class I area. These annual averages are then translated into estimates for the best 20% and worst 20% days needed for the progress assessment. Extinction was assumed to have a lognormal frequency distribution; deciviews would then have a normal distribution, and its 10th and 90th percentiles were used as estimates of the average of the best 20% and worst 20% of days, respectively. The result is a table of best and worst 20% deciview values for each Class I area, which appears in Appendix B of the guidance. The guidance also allows States to use a refined alternative to this default approach for estimating natural conditions.

Finally, the uniform rate of progress is calculated as the difference between the baseline and natural conditions, spread over the 60 years between 2004 and 2064: uniform deciviews per year improvement = (current 2004 deciviews - natural 2064 deciviews) / 60. This rate is the benchmark against which visibility improvement is to be compared by the State; the first planning period envisaged by the Regional Haze Rule is through 2018, so this uniform rate is multiplied by 14 to determine the first benchmark.

2.2 CALCULATION OF VISIBILITY FROM IMPROVE MEASUREMENTS

The CENRAP procedure used for developing a uniform rate of progress (URP, also known as "glide path" or "glide slope") for the State of Arkansas followed EPA guidance contained in the GTR and GENVC with the exception that the revised IMPROVE algorithm was utilized rather than the original IMPROVE equation . The procedure used is described in the Technical Support Document for CENRAP Emissions and Air Quality Modeling to Support Regional Haze State Implementation Plans.[4]

CENRAP used the approach of Pitchford et al.[5] The equation utilized is referred to as the “revised” IMPROVE algorithm or equation and was used for estimates of both baseline and natural conditions. The revised IMPROVE equation is used to convert measured concentrations into extinction for each pollutant chemical species, and then total them up, accounting for the effect of relative humidity, and including the Rayleigh scattering that occurs in pure air. The extinction total is then used to calculate deciviews for use in visibility progress assessments through equation 1. EPA’s 2007 “Guidance on the Use of Models and Other Analyses for

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[2] Hereafter “GENVC”: EPA, 2003, *Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program*, EPA-454/B-03-005, September 2003, EPA OAQPS; web page: http://www.epa.gov/ttn/oarpg/t1pgm.html direct link: http://www.epa.gov/ttn/oarpg/t1/memoranda/rh_envcurhr_gd.pdf

[3] Trijonis, J.C., et al., 1990, "Visibility: Existing and Historical Conditions-Causes and Effects", chapter 24 in NAPAP State of Science & Technology, Vol. III web page: http://vista.cira.colostate.edu/improve/Publications/Principle_pubs.htm

[4] Hereafter “CENRAP TSD”: Environ International Corp. and University of California at Riverside, September 2007.

[5] Pitchford, Marc; William Malm, Bret Schichtel, Naresh Kumar, Douglas Lowenthal, and Jenny Hand, 2007: Revised algorithm for estimating light extinction from IMPROVE particle speciation data. J. Air & Waste Manage. Assoc., 57, 1326-1336.

Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze"[6] states that the use of either the IMPROVE or the revised IMPROVE equation is acceptable provided that the States supply documentation concerning the choice of equation and that the same algorithm is utilized for both the base and future extinction calculations.

The IMPROVE program revised the IMPROVE equation after a scientific assessment of its implications for regional haze planning to reduce biases in light extinction estimates compared to the old algorithm.[7] In particular, when compared to nephelometer direct measurements of visibility extinction, the original IMPROVE equation over-predicts for low extinction conditions and under-predicts for high extinction. These biases have direct relevance for estimates for the best 20% and worst 20% visibility days that are used to assess progress.

The revised equation used by CENRAP has four changes: 1) greater completeness though the inclusion of sea salt, which can be important for coastal sites; 2) increased organic carbon mass estimate, based on more recent data for remote areas; 3) Rayleigh scattering using site-specific elevation and temperature, a refinement over the older network-wide constant; and 4) separate estimates for small and large particles of visibility impacts and humidity-dependent particle size growth rates, which could affect estimates at the low and high ends.[8] The revised equation has an additional term for inclusion of NO2; however, none of the CENRAP Class I areas have monitors that provide observations of NO2 so this term was not used.

The new equation shows broader scatter overall, but less bias in matching visibility measurements under high and low visibility conditions. That is, though it has a somewhat worse fit considering all the data, it has a better fit under visibility conditions most relevant to regional haze planning, the best and worst 20% of days. The looser overall fit can cause a slightly different set of days to be the ones chosen as the 20% worst, but the chemical species composition for such days is little changed (IMPROVE technical subcommittee for algorithm review, 2001, pp. 11-12), and so this makes little difference for assessing the contribution of emission sources to current conditions, and for projecting the effect of emission controls. The split between small and large particles was the main factor in reducing the biases.

The organic carbon (OC) measured by the IMPROVE network does not include all organic matter (OM); based on 1970's urban data, a scaling factor of 1.4 is embedded in the old equation to account for the full mass. Based on recent data more relevant to relatively remote Class I areas, the revised IMPROVE equation embeds an OM/OC factor of 1.8. At the Caney Creek

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[6] Hereafter "GOPMRH": EPA, 2007, *Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze*, EPA-454/B-07-002, April 2007, EPA OAQPS; web page: http://www.epa.gov/scram001/guidance_sip.htm direct link: http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf

[7] IMPROVE, 2006, *Revised IMPROVE algorithm for Esimating Light Extinction from Particle Speciation Data*, January 2006; http://vista.cira.colostate.edu/improve/Publications/GrayLit/gray_literature.htm; Hand, J.L.; Douglas, S.G., 2006, Review of the IMPROVE Equation for Estimating Ambient Light Extinction Coefficients – Final Report, http://vista.cira.colostate.edu/improve/Publications/GrayLit/016_IMPROVEEeqReview/IMPROVEeqReview.htm

[8] Pitchford, Marc, 2006, "New IMPROVE algorithm for estimating light extinction approved for use", *The IMPROVE Newsletter*, Volume 14, Number 4, Air Resource Specialists, Inc.; web page: http://vista.cira.colostate.edu/improve/Publications/news_letters.htm direct link: http://vista.cira.colostate.edu/improve/Publications/NewsLetters/IMPNews4thQtr2005.pdf

Wilderness Area and Upper Buffalo Wilderness Area sites, fine sulfurous aerosol contributes the most to visibility impairment on the worst days during the baseline years, although a few of the worst days are dominated by nitrates. . The largest difference in results between the two algorithms is related to the separation of total concentrations of sulfate, nitrate, and organic carbon into small and large size distributions in the revised equation.

The revised IMPROVE equation has less bias, is more refined, accounts for more pollutants, incorporates more recent data, and is based on considerations of relevance for the calculations needed for assessing progress under the RHR. EPA believes it is appropriate for the CENRAP states to use the revised IMPROVE equation.

2.3 BASELINE VISIBILITY CONDITIONS

Section 2 of the EPA's "Guidance for Tracking Progress Under the Regional Haze Rule" ("GTP") describes a step-by-step process for calculating the visibility metric for the baseline period 2000-2004. The steps involve (1) assembly of daily species concentration data from the IMPROVE network, (2) inclusion of substitutions for missing data; (3) assessment of site data completeness (4) calculation of extinction via the IMPROVE equation; (5) calculation of the deciview Haze Index; (6) calculation of average deciviews for the 20% best and 20% worst days for each year; and (7) averaging these over the 5 year period. These steps are mostly straightforward and are briefly discussed here with a more detailed discussion on the differences between EPA guidance and CENRAP procedures.

For data substitution, the EPA guidance describes two procedures. The first is the use of quarterly median concentrations. This is the median concentration from the quarter the data value is missing from, averaged with similar medians from the preceding four years, using only quarters with having at least 50% of the days available and no more than 10 consecutive missing days (GTP, "Step 3: Determine Quarterly Median Concentrations for Missing Variables", p.2-5). The second substitution involves using quarterly averages, as long as the substitution changes extinction values by less than 10% in 90% of the data (GRP, "Step 5 - Evaluate Feasibility of Substituting Average Values", pp. 2-7 - 2-8).

Completeness requirements are also given in the EPA guidance: to be complete and included in the progress calculation, a year must have data for 50% of the sampling days in every quarter, 75% of the days for the year overall, and no more than 10 consecutive missing sampling days; the overall 5-year period must have at least 3 complete years of data (GTP, "Step 7 - Check Data Completeness", pp. 2-8 - 2-9).

The RHR defines the baseline period as the five year span from 2000-2004. IMPROVE monitors were established at the Caney Creek Wilderness Area site located on Eagle Mountain, Polk County, Arkansas and at the Upper Buffalo Wilderness Area located in Deer, Newton County, Arkansas and collected samples for the two Class I areas in the state of Arkansas. Data for the Caney Creek Wilderness Area site that meet the completeness requirements are available for the 2002-2004 portion of this baseline period. Therefore, baseline visibility was calculated based on the average of the worst (best) 20% of days for each of these three years. This meets the minimum overall data completeness requirements for calculation of the baseline visibility conditions detailed in the GTP. Data for the Upper Buffalo Wilderness Area from 2000 through 2004 were averaged for the worst (best) 20% of days to calculate baseline visibility conditions for the site.

Every Class I area within the CENRAP states has an associated IMPROVE monitor. Results from analysis of samples collected at each monitor site are used to calculate extinction and haze index using the procedure described above. For those CENRAP sites (Breton Island (BRET), Louisiana; Boundary Waters (BOWA), Minnesota and Mingo (MING), Missouri) that did not have three valid years that met the completeness requirements for inclusion in the baseline visibility calculations, data filling was used to create at least three years of valid data. These data filled IMPROVE databases were prepared and made available on the VIEWS website. More information on the data filling procedures can be found at the VIEWS website: (http://vista.cira.colostate.edu/views/).

The CENRAP followed EPA guidance for estimating baseline visibility conditions.

2.4 Natural Visibility Conditions

EPA guidance set out a default procedure for estimating natural conditions, but also describes circumstances when States might want to use a more refined approach, such as to reduce uncertainty when baseline visibility is already near natural conditions, or when there is marked seasonality; these might be accomplished via alternative estimates of natural concentrations, or use of temporally varying estimates (GENV sec. 3.1 and 3.2).

ADEQ opted to use the revised IMPROVE equation to calculate the "refined" natural visibility conditions. This is an acceptable approach under our 2003 Natural Visibility Guidance. This approach uses the revised IMPROVE equation so that progress between baseline conditions and natural conditions can be calculated on a consistent basis.

The procedure used has several acknowledged limitations. 1) each chemical species can have one of only two possible background concentrations, one for the East and one for the West. Future efforts may provide for a larger number of geographic zones with differing concentrations A second potential limitation is that the same approach is used for both natural- and anthropogenic-dominated species components; EPA guidance mentions the possibility of treating these separately (GENV sec. 3.4).

The majority of visibility impairment at the Caney Creek Wilderness Area and Upper Buffalo Wilderness Area site is currently from anthropogenic sources. As measures are taken to improve visibility and decrease emissions, the ability to identify natural sources and background concentrations of PM will improve. The current approach used by ADEQ follows EPA methods and is acceptable. As additional information and more site-specific data become available, ADEQ is encouraged to pursue refinements in this approach to better quantify natural visibility conditions.

2.5 Uniform Rate of Progress (Glidepath) Calculation

The uniform rate of progress is calculated as the linear rate of progress (decrease in deciviews per year) required to reach natural visibility conditions in 2064, starting from the baseline conditions in 2004. The first benchmark year is 2018 and the calculated improvement required to attain the desired rate of progress is 3.45 deciviews for Caney Creek and 3.43 dv for Upper Buffalo. Tables 2.5 and 2.6 summarize the calculations performed by ADEQ.

Table 2.5. Uniform Rate of Progress for Caney Creek Wilderness Area and (worst quintile, western natural visibility conditions)

Conditions	**Total extinction (Mm^{-1})**	**Haze Index (deciviews)**
Baseline (2002-2004) conditions	134.1	26.36
Natural (for 2064) conditions	21.16	11.58
Observed impairment above natural conditions	112.94	14.78
Progress (2004-2018) at uniform rate		.246 per year
Improvement needed by 2018 assuming uniform rate of progress	26.35	3.45

Table 2.6. Uniform Rate of Progress for Upper Buffalo Wilderness Area (worst quintile, western natural visibility conditions)

Conditions	**Total extinction (Mm^{-1})**	**Haze Index (deciviews)**
Baseline (2002-2004) conditions	131.95	26.27
Natural (for 2064) conditions	21.54	11.57
Observed impairment above natural conditions	110.41	14.70
Progress (2004-2018) at uniform rate		.245 per year
Improvement needed by 2018 assuming uniform rate of progress	25.76	3.43

Chapter 3: Emission Inventory Development

3.1 INTRODUCTION

In support of the CENRAP Regional Haze air quality modeling efforts, air quality modeling inputs including annual meteorology and emissions inventories for a 2002 actual emissions base case, a planning case to represent the 2000-04 regional haze baseline period using averages for key emissions categories, and a 2018 base case of projected emissions are needed. All emission inventories were developed using the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (See section 3.6). Each of these inventories has undergone a number of revisions throughout the development process to arrive at the final versions used in CMAQ and CAMx air quality modeling. In general, updated 2002 emissions data for the U.S. developed by the Regional Planning Organizations (RPOs), updated emissions data for Mexico from the BRAVO 1999 emissions inventory, and version 2 of the 2000 emissions data for Canada were used to generate a 2002 annual emissions database. The 2002 and 2018 emissions inventories and ancillary modeling data were provided by CENRAP emissions inventory contractors,[9] other RPOs and EPA. Emission modeling and quality assurance (QA) work was based on the *Quality Assurance Project Plan (QAPP) CENRAP Emissions and Air Quality Modeling*[10] and *Protocol for the CENRAP 2002 Annual Emissions and Air Quality Modeling*[11] (hereafter referred to as the "Modeling Protocol"). These protocols were reviewed by the EPA Regions at the time they were developed.

The development of each of these emission scenarios are as follows:

- The 2002 base case emissions scenario was developed to represent the actual conditions in calendar year 2002 with respect to ambient air quality and the associated sources of criteria and particulate matter air pollutants. This emission inventory is used to validate the air quality model and associated databases and to demonstrate acceptable model performance with respect to replicating observed particulate matter air quality. The base case includes actual day-specific emissions of SO_2 and NOx emissions for large stationary point sources based on measured continuous emissions monitoring (CEM) data along with actual 2002 fire emissions.

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[9] Pechan and CEP. 2005. Consolidation of Emissions Inventories (Schedule 9; Work Item 3). E.H. Pechan and Associates, Inc. and Carolina Environmental Program (CEP), University of North Carolina(UNC), (http://www.cenrap.org/html/projects.php?mode=subcatdownload&id=50); Pechan and CEP. 2005. Refinements of CENRAP's 2002 Emissions Inventories (Schedule 9; Work Item 3). E.H. Pechan and Associates, Inc. and CEP, UNC. (http://www.dnr.mo.gov/env/apcp/docs/appendixh-3.pdf); Reid, S.B. et al. 2004. Emission Inventory Development for Mobile Sources and Agricultural Dust Sources for the Central States. Sonoma Technology, Inc. (http://cenrap.sonomatech.com/CENRAP_Mobile/FinalReport.pdf).; Reid, S.B et al. 2004. Research and Development of Planned Burning Emission Inventories for the Central States Regional Air Planning Association. Sonoma Technology, Inc. (http://cenrap.sonomatech.com/CENRAP_PlannedBurnData/FinalReport.pdf).; Coe, D.L. and S.B. Reid. 2003. Research and Development of Ammonia Emission Inventories for the Central States Regional Air Planning Association. Sonoma Technology, Inc. (http://cenrap.sonomatech.com/CENRAP_Ammonia_NIF/FinalReport.pdf).

[10] Morris, R.E. and G. Tonnesen. 2006. Quality Assurance Project Plan (Draft) for Central Regional Air Planning Association (CENRAP) Emissions and Air Quality Modeling. (http://pah.cert.ucr.edu/aqm/cenrap/docs/CENRAP_QAPP_Rev3_Mar_29_2006.pdf)

[11] Morris, R.E. et al. Modeling Protocol for the CENRAP 2002 Annual Emissions and Air Quality Modeling, Draft 2.0. Web:http://pah.cert.ucr.edu/aqm/cenrap/docs/CENRAP_Draft2.0_Modeling_Protocol_120804.pdf).

- The 2000-04 baseline period planning case emissions scenario is referred to as "Typ02G". The purpose of the Typ02G inventory is to represent baseline emission patterns based on average, or "typical", conditions. This inventory provides a basis for comparison with the future year 2018 projected emissions, as well as to gauge reasonable progress with respect to future year visibility. 5-years of CEM data were analyzed and typical seasonal and diurnally varying emissions were defined.

- The 2018 future-year base case emissions scenario is referred to as "2018 Base Case" or "Base18G". These emissions are used to represent conditions in future year 2018 with respect to sources of criteria and particulate matter air pollutants, taking into consideration growth and controls. Modeling results based on this emission inventory are used to define the future year ambient air quality and visibility metrics.

Emission inventory data from five general categories are needed to support air quality modeling: stationary point-source emissions, stationary area-source emissions (also called nonpoint), mobile emissions for on-road sources, mobile emissions for nonroad sources (including aircraft, railroad, and marine vessels), and biogenic emissions. The emission inventory development and emissions modeling steps can be different for each of these categories. The *Technical Support Document for CENRAP Emissions and Air Quality Modeling to Support Regional Haze State Implementation Plans*[12] (hereafter referred to as the "CENRAP TSD") describes the development of each source category inventory is detail. Appendix B of the CENRAP TSD lists the file names, data source, type and a description of emissions used in the 2002 typical (Typ02G) emissions inventory. Emissions inventories for each source category are described briefly in the following section. The CENRAP TSD is included as Appendix 48.1of the ADEQ Regional Haze Implementation Plan Revision.

3.2 2002 EMISSIONS INVENTORY

ADEQ developed the 2002 point source emissions inventory in-house with Emission Inventory Questionnaires and used the biogenic source inventory developed by EPA.ADEQ contracted with ENVIRON to develop an emission inventory for three inventory source classifications: on-road and non-road mobile sources and nonpoint sources for the baseline year of 2002.[13]

The nonpoint, or area source, inventory includes emitters of ozone pollutants (i.e., NOx and VOCs) such as devices that combust fuel (e.g., dry cleaners, degreasing, and industrial surface coating), gasoline distribution, asphalt paving, and fires and open burning (e.g., agricultural burning, structural fires, wildfires, prescribed burning). In addition, area source categories contributing to visibility pollutants (i.e., PM10, PM2.5, and NH3) are also included in the area source emissions inventory (e.g., fugitive dust, agricultural operations, livestock ammonia, etc.).

[12] Environ International Corp. and University of California at Riverside, 2007. Technical Support Document for CENRAP Emissions and Air Quality Modeling to Support Regional Haze State Implementation Plans. (http://www.cenrap.org/html/projects.php?mode=download&id=87)

[13] Final Report: Arkansas 2002 Emission Inventory, prepared by ENVIRON and Eastern Research Group, May 13, 2004 (Appendix 7.1A of the RH SIP)

The contractor reviewed all emission factors used in the inventory to ensure they were the most appropriate and up-to-date emission factors available and checked all calculations for accuracy.

The 2002 national emissions inventory (2002 NEI), compiled from submitted inventories from states, tribal and local agencies was the original basis for the CENRAP emission inventory. Sonoma Technology supplemented the 2002 NEI data with non-point source inventories to address agricultural and prescribed burning, on-road and non-road mobile sources, agricultural tilling and livestock dust, and agricultural ammonia for the CENRAP inventory.[14]

Table 3-1. Emissions from Arkansas Sources (tons/yr)

	VOC	**NOx**	**PM2.5**	**PM10**	**NH3**	**CO**	**SO2**
Point	44,329	72,419	7,837	12,406	1	56,366	92,205
Area	93,548	24,450	68,000	148,433	152,436	436,525	29,889
Non-road mobile	54,785	62,472	5,220	5,673	49	272,627	5,490
On-road mobile	48,599	141,894	3,021	3,784	2,480	669,214	3,902
Biogenic	1,385,666	18,960				136,688	
Total	*1,626,927*	*323,195*	*84,078*	*170,296*	*154,967*	*1,571,419*	*131,485*

3.2.1 Stationary Point-Source Emissions

Point sources are typically regulated and information on emissions and locations are available in regulatory reports. Larger permitted point sources in Arkansas are required to submit annual emissions inventories via Emission Inventory Questionnaires (EIQ), and all other point sources have a reporting frequency of every 3 years, beginning with the 2002 base inventory. This data, along with similar data available from other states make the basis of the point source inventory. The CENRAP stationary-point inventory consisted of annual county-level and tribal data provided in August of 2005.[15] Point source inventories were developed by the other RPOs and shared with CENRAP. These inventories are typically further divided into EGU and non-EGU sources. For EGU sources, continuous emissions monitoring (CEM) data is available to create day and hour-specific emission inventories for input into the Base02F inventory. The Typ02G

[14] Reid, S.B. et al. 2004. Emission Inventory Development for Mobile Sources and Agricultural Dust Sources for the Central States. Sonoma Technology, Inc. (http://cenrap.sonomatech.com/CENRAP_Mobile/FinalReport.pdf).; Reid, S.B et al. 2004. Research and Development of Planned Burning Emission Inventories for the Central States Regional Air Planning Association. Sonoma Technology, Inc. (http://cenrap.sonomatech.com/CENRAP_PlannedBurnData/FinalReport.pdf).; Coe, D.L. and S.B. Reid. 2003. Research and Development of Ammonia Emission Inventories for the Central States Regional Air Planning Association. Sonoma Technology, Inc.

[15] Pechanand CEP. 2005. Consolidation of Emissions Inventories (Schedule 9; Work Item 3). E.H. Pechan and Associates, Inc. and CEP, UNC, (http://www.cenrap.org/html/projects.php?mode=subcatdownload&id=50); Pechan and CEP. 2005. Refinements of CENRAP's 2002 Emissions Inventories (Schedule 9; Work Item 3). E.H. Pechan and Associates, Inc. and CEP, UNC. (http://www.dnr.mo.gov/env/apcp/docs/appendixh-3.pdf)

inventory includes further processing of EGU emissions to develop a typical emission levels and temporal profiles.

Coal-fired point sources within the CENRAP states use a PM2.5 speciation profile recently developed for MRPO by Carnegie Mellon that is representative of combustion of eastern bituminous coal. Texas and North Dakota sources that burn lignite coal used a modified NCOAL speciation.[16] More specific speciation profiles should be utilized as they become available to accurately describe the speciation of PM2.5 from combustion of different types of coal utilized in Arkansas.

3.2.2 On-Road Mobile Emissions

Emissions from mobile, on-road sources are prepared for CENRAP modeling in one of two ways: 1) pre-computed emissions supplied by an RPO or other group or 2) supplied vehicle miles traveled (VMT), meteorological data and other MOBILE6[17] inputs for calculation in SMOKE/MOBILE6. Annual mobile emissions were pre-computed as part of the 1999 Mexico inventory and 2000 Canada inventory. Seasonal mobile emissions calculated in MOBILE6 were provided for all 13 WRAP states. For all other RPOs, including CENRAP, county-level VMT were prepared and input into SMOKE/MOBILE6. . For all Arkansas counties, county-level Highway Performance Monitoring System annual average VMT data were used. Data for 2007 and 2010 were extrapolated back to 2002. Annual average data was adjusted using seasonal factors to arrive at month-specific estimates. Weekday VMT for summer and winter were estimated from monthly values using Texas statewide average weekday/annual average daily factors.[18] For the other CENRAP states, Sonoma Technology provided monthly VMT data and MOBILE6 input files for the months of January and July for all counties in the CENRAP region.[19] MOBILE6 input files for the remaining months of 2002 had to be generated. The EPA MOBILE6 was state-of-the-science at the time the modeling was conducted and deemed acceptable at that time. EPA Office of Transportation and Air Quality has developed a new model, Motor Vehicle Emission Simulator (MOVES), which will replace the MOBILE6 model for estimating emissions from on-road mobile sources.

3.2.3 Biogenic Emissions

The BEIS3 system is utilized to estimate emissions from biogenic sources. BEIS3 is integrated into SMOKE for deriving biogenic emissions estimates given land use information, emissions factors for different plant species, and hourly, gridded meteorology data. Land use data is from the BELD3 land use database and emission factors used are version 0.98 of the BELD emissions factors. These land use data and emission factors were developed by the WRAP during their

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[16] Chow,J et al. 2004. Source Profiles for Industrial, Mobile, and Area Sources in the Big Bend Regional Aerosol Visibility and Observational Study. Chemosphere 54, 185-208.

[17] EPA's MOBILE6 model is available at http://www.epa.gov/OMSWWW/m6.htm

[18] Final Report: Arkansas 2002 Emission Inventory, prepared by ENVIRON and Eastern Research Group, May 13, 2004 (Appendix 7.1A of the RH SIP)

[19] Reid, S.B. et al. 2004. Emission Inventory Development for Mobile Sources and Agricultural Dust Sources for the Central States. Sonoma Technology, Inc. (http://cenrap.sonomatech.com/CENRAP_Mobile/FinalReport.pdf)

preliminary modeling efforts. BEIS modeling produces gridded, hourly emissions for input into CMAQ and CAMx.[20] The EPA approves of the use of BEIS3 by CENRAP in this SIP.

3.2.4 Non-Road Mobile Emissions

Emissions from aircraft operations, commercial and recreational marine vessels, and railroad locomotives and other sources were developed by the EPA for the 2002 NEI. The EPA NONROAD[21] model was utilized by Sonoma Technology to develop a non-road emissions inventory for the CENRAP states.**Error! Bookmark not defined.** EPA and CENRAP emissions were consolidated by Pechan and CEP.[22]

3.2.5 Area Source Emissions

The area source inventory includes data from the EPA 2002 NEI and inventories prepared by ADEQ, CENRAP and other CENRAP states. Sonoma Technology prepared additional inventories of prescribed burning, agricultural dust, and soil agricultural ammonia for the CENRAP region.[23] ADEQ used 2001 EIQ data for fuel use to estimate area source fuel combustion emissions. The Western Regional Air Partnership (WRAP) provided an oil and gas production inventory for states within the WRAP that included a number of states in the CENRAP modeling domain. These emissions were consolidated by Pechan and CEP.[24] UCR processed this inventory further to separate the inventory into subcategories (general area, fire, ammonia, road dust, fugitive dust, uncategorized) to assist in particulate source apportionment modeling with CAMx.

3.3 2018 EMISSIONS INVENTORY

An emission inventory for 2018 including anticipated changes due to population growth, emission controls and development of industry, energy, and natural resources is required to project the net effect on visibility conditions by 2018. CENRAP developed an emission inventory for 2018 (Base18G) using a combination of EPA Economic Growth Analysis System (EGAS 5), MOBILE 6, NONROAD, and the Integrated Planning Model (IPM) of ICF

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[20] Tonnesen, G., et al. 2005. Final Report for the Western Regional Air Partnership (WRAP) Regional Modeling Center (RMC) for the Project Period March 1, 2004 through February 28, 2005. UCR. (http://pah.cert.ucr.edu/aqm/308/reports/final/2004_RMC_final_report_main_body.pdf).

[21] NONROAD is available at http://www.epa.gov/otaq/nonrdmdl.htm

[22] Pechan and CEP. 2005. Consolidation of Emissions Inventories (Schedule 9; Work Item 3). E.H. Pechan and Associates, Inc. and CEP, UNC, (http://www.cenrap.org/html/projects.php?mode=subcatdownload&id=50)

[23] Reid, S.B. et al. 2004. Emission Inventory Development for Mobile Sources and Agricultural Dust Sources for the Central States. Sonoma Technology, Inc. (http://cenrap.sonomatech.com/CENRAP_Mobile/FinalReport.pdf).; Reid, S.B et al. 2004. Research and Development of Planned Burning Emission Inventories for the Central States Regional Air Planning Association. Sonoma Technology, Inc. (http://cenrap.sonomatech.com/CENRAP_PlannedBurnData/FinalReport.pdf).; Coe, D.L. and S.B. Reid. 2003. Research and Development of Ammonia Emission Inventories for the Central States Regional Air Planning Association. Sonoma Technology, Inc.

[24] Pechan and CEP. 2005. Consolidation of Emissions Inventories (Schedule 9; Work Item 3). E.H. Pechan and Associates, Inc. and Carolina Environmental Program (CEP), University of North Carolina(UNC), (http://www.cenrap.org/html/projects.php?mode=subcatdownload&id=50); Pechan and CEP. 2005. Refinements of CENRAP's 2002 Emissions Inventories (Schedule 9; Work Item 3). E.H. Pechan and Associates, Inc. and CEP, UNC. (http://www.dnr.mo.gov/env/apcp/docs/appendixh-3.pdf)

International for EGUs to project emissions from 2002 to 2018. Emission projections for most source categories are based on growth and control factors compiled by Pechan and detailed in the *Development of Growth and Control Inputs for CENRAP 2018 Emissions* draft technical support document.[25]

Table 3-2. Emission estimates for Arkansas sources in 2018 (tons/yr)

	VOC	NOx	PM2.5	PM10	NH3	CO	SO2
Point	55,603	71,107	13,775	19,799	2,575	75,708	106,461
Area	107,387	31,531	69,585	148,592	201,722	448,760	31,169
Non-road mobile	31,475	34,305	3,387	3,678	49	293,734	211
On-road mobile	19,924	33,460	949	949	3,412	367,152	443
Biogenic	1,385,666	18,960				136,688	
Total	*1,600,055*	*189,542*	*87,695*	*173,019*	*207,758*	*1,322,043*	*138,283*

Table 3-3. Change in Arkansas emissions from 2002 to 2018

	VOC	NOx	PM2.5	PM10	NH3	CO	SO2
Point	11,274	-1,312	5,938	7,393	2,574	19,342	14,256
Area	13,839	7,081	1,585	159	49,286	12,235	1,280
Non-road mobile	-23,310	-28,167	-1,833	-1,995	0	21,107	-5,279
On-road mobile	-28,675	-108,434	-2,072	-2,835	932	-302,062	-3,459
Biogenic	0	0	0	0	0	0	0
Net change	-26,872	-133,653	3,617	2,723	52,791	-249,376	6,798
% change	-2%	-41%	4%	2%	34%	-16%	5%

Pechan used the following alternative data sources to replace EGAS default projections:

- County-level population projections for CENRAP states;
- Annual Energy Outlook (AEO) projections for oil and gas production emissions;
- average historical values rather than 2002 data for prescribed burning;
- Extrapolation of historical trends for unpaved roads;
- United States Department of Agriculture (USDA) projections of planted acreage; for major crops for crop tilling emissions;
- Onroad vehicle miles traveled projections for paved road fugitive dust emissions;
- USDA livestock projections

[25] Pechan 2005. Development of Growth and Control Inputs for CENRAP 2018 Emissions, Draft Technical Support Document. E.H. Pechan and Associates, Inc. (http://www.dnr.mo.gov/env/apcp/docs/appendixh-4.pdf)

All control strategies expected to take effect prior to 2018 are included in the projected emission inventory. Maximum Achievable Control Technology (MACT) regulations were applied to those engines subject to MACT rules. Emissions for Canada are based on a shared 2020 emission inventory. 2018 EGU emissions were based on the run 2.1.9 of the Integrated Planning Model (IPM) updated by the CENRAP states. Reductions anticipated from BART controls for EGUs in Oklahoma, Arkansas, Kansas, and Nebraska were included in projections of 2018 emissions. These anticipated reductions were based on actual operating conditions and estimated control efficiencies from utilities. In the State's September 27, 2011 supplemental submission, ADEQ clarified that it provided the CENRAP Modeling Workgroup with the controlled BART source emission limits contained in the State's RH Rule, the APC&E Commission Regulation 19, Chapter 15, for inclusion in the CENRAP's 2018 future case modeling. Newly permitted coal-fired utilities were included in 2018 projections. Conservatively, no IPM projected new units were removed from the simulation with the addition of the permitted facilities. Appendix B of the CENRAP TSD lists the file names, data source, type and a description of emissions used in the 2018 (Base18G) emissions inventory. We note that emissions of sulfate from point sources in Arkansas are projected to increase by over 14,000 tons/yr in 2018 from 2002 levels.

The following sources were assumed to remain constant between the 2002 and 2018 base case simulations:

- Biogenic VOC and NOx emissions from the BEIS3 biogenic emissions model;
- Wind blown dust associated with non-agricultural sources (i.e., natural wind blown fugitive dust);
- Off-shore emissions associated with off-shore marine and oil and gas production activities;
- Emissions from wildfires;
- Emissions from Mexico; and
- Global transport (i.e., emissions due to BCs from the 2002 GEOS-CHEM global chemistry model.

The last future runs (2018G) utilized an inventory that had assumptions about BART controls in the CENRAP states.

Chapter 4: Modeling Protocol, Episode Selection and Modeling Set-up Overview

4.1 INTRODUCTION

Meteorological, emission and photochemical models are essential tools in examining factors that impact visibility and for development of effective control strategies to meet the goals and requirements of the RHR. CENRAP selected the team of ENVIRON and UCR to perform the needed emissions and air quality modeling. The team performed regional haze analyses by operating regional scale, three-dimensional air quality models to simulate the transport and fate of key species that affect visibility in Class I Areas in the central U.S. This work included the development of meteorological data for input into the model as well as creation and processing of emission estimates for use in the model. The Modeling Protocol[26] describes the model selection, configuration, episode selection, and model evaluation used in support of the Arkansas RHR SIP.

4.2 QUALITY ASSURANCE PROGRAM PLAN

The modeling team developed a quality assurance program plan (QAPP)[27] to develop clearly defined data quality objectives, documentation, and procedures. This QAPP was developed incorporating the following elements as described in the EPA guidance document for modeling:

- A systematic planning process including identification of assessments and related performance criteria;
- Peer reviewed theory and equations;
- A carefully designed life-cycle development process that minimizes errors;
- Documentation of any changes from original plans;
- Clear documentation of assumptions, theory, and parameterization that is detailed enough so others can understand the model output;
- Input data and parameters that are accurate and appropriate for the problem; and
- Output data that can be used to help inform decision makers.

The plan describes the data management and quality assurance/quality control measures taken to assure high quality emission inventories and air quality modeling results for use in the RH analysis.

4.3 EPISODE SELECTION

EPA guidance[28] describes the criteria that should be used to select a modeling episode. The modeling episode should: 1) reflect a variety of meteorological conditions that are representative of the 20% worst and 20% best days in the Class I areas being modeled, 2) be representative of

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[26] Morris, R.E. et al. Modeling Protocol for the CENRAP 2002 Annual Emissions and Air Quality Modeling, Draft 2.0. Web:http://pah.cert.ucr.edu/aqm/cenrap/docs/CENRAP_Draft2.0_Modeling_Protocol_120804.pdf).

[27] Morris, R.E. and G. Tonnesen. 2004. Quality Assurance Project Plan (Draft) for Central Regional Air Planning Association (CENRAP) Emissions and Air Quality Modeling. (http://pah.cert.ucr.edu/aqm/cenrap/docs/CENRAP_QAPP_Nov_24_2004.pdf). December 23.

[28] EPA, 2007. *Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze*, EPA-454/B-07-002, April 2007, EPA OAQPS; (http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf)

the baseline period of 2000-2004, 3) cover a period where extensive air quality/meteorological data are available, 4) cover a long enough period so that relative response factors (RRF) can be averaged over a period several days (> 10 days). For regional haze modeling, the preferred approach is to simulate an entire representative year. This allows the states to base RRF values on the 20% best and 20% worst days of the year.

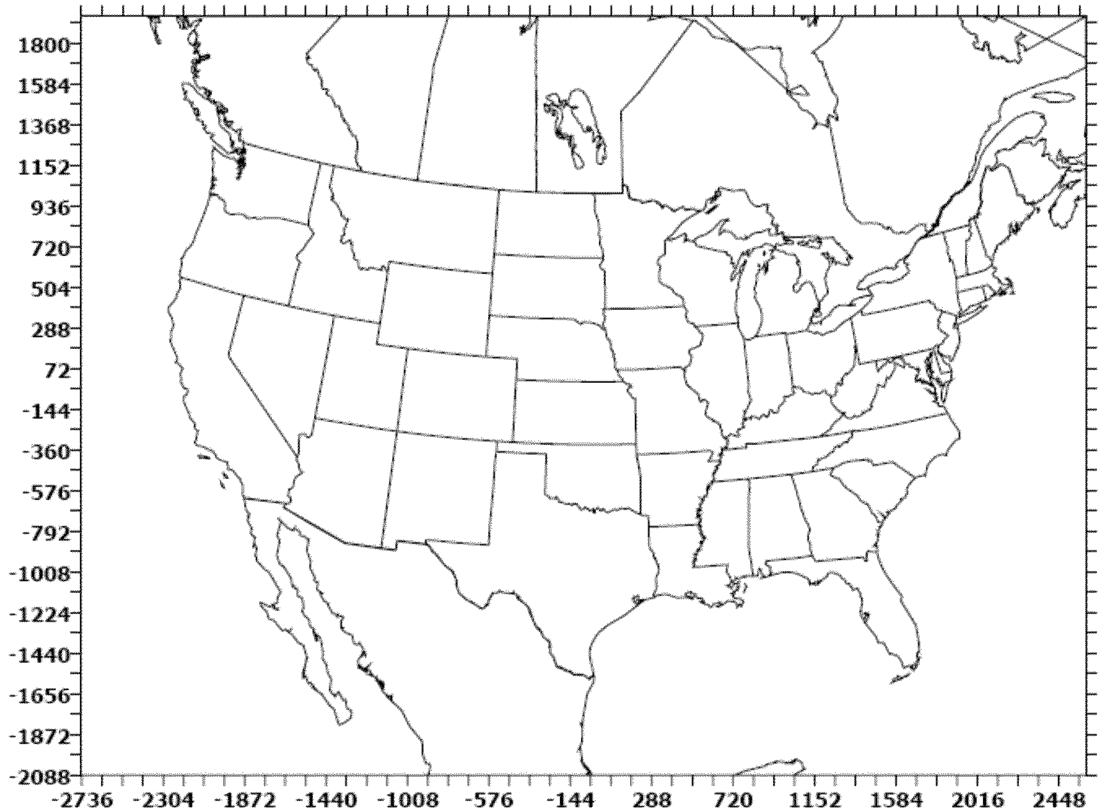
CENRAP selected the entire calendar year of 2002 for regional haze modeling. This is consistent with the EPA guidance and has the added benefit of the base case and baseline inventories covering the same year. Other RPOs selected the same modeling year, allowing for more direct comparison of modeling results and sharing of modeling inputs. The availability of 2002 NEI also provides an additional resource in the development of emission inventories for the modeling episode. 2002 appears to be a more representative year when compared to 2003 and 2004. The EPA approves of the selection of 2002 for the regional haze modeling episode.

4.4 PHOTOCHEMICAL AND EMISSIONS MODELING DOMAIN

CENRAP conducted emissions and air quality modeling on the 36-km national regional planning organization (RPO) domain. This domain consists of a 148 × 112 array of 36-km × 36-km grid cells and covers the continental United States. Additional photochemical modeling runs were performed on a 12-km domain covering the central states to examine the sensitivity of model results to domain resolution. These results were similar to the 36 km results so CENRAP determined that the 36-km modeling domain was sufficient for the 2002 annual modeling.[29] CENRAP's choice of 36 km horizontal resolution was appropriate given the lack of improved performance at 12 km resolution and the additional computational resources required to run the model at the higher resolution. The use of higher spatial resolution modeling should be revisited in future modeling efforts as computational efficiency improves.

[29] Morris, R.E. et al. 2006. CENRAP Modeling: Need for 36 km versus 12 km Grid Resolution. Presented at CENRAP Modeling Work Group Meeting, Baton Rouge, Louisiana. (http://pah.cert.ucr.edu/aqm/cenrap/ppt_files/ Morris_36vs12km_Feb6-8_2006.ppt).

Figure 4-1. National RPO 36-km modeling domain for CMAQ, CAMx, and SMOKE modeling.



4.5 MM5 METEOROLOGICAL MODEL

4.5.1 Model Selection

Photochemical grid models, such as CMAQ and CAMx, require inputs of three-dimensional gridded meteorological data, including wind, temperature, humidity, cloud/precipitation, and boundary layer parameters. The Fifth-Generation Penn State/NCAR Mesoscale Model (MM5) was used to develop these input fields for the CENRAP visibility modeling as well as inputs for the SMOKE emissions processing tool. MM5 is a state-of-the-science atmosphere model that has proven useful for air quality applications and has been used extensively in past local, state, regional, and national modeling efforts. MM5 has undergone extensive peer-review, with all of its components continually undergoing development and scrutiny by the modeling community. In-depth descriptions of MM5[30] can be found in Dudhia (1993)[31] and Grell et al. (1994).[32] All meteorological data used for the CENRAP air quality modeling efforts are derived from MM5 model simulations.

30 http://www.mmm.ucar.edu/mm5

31 Dudhia, J., 1993. "A non-hydrostatic version of the Penn State/NCAR Mesoscale Model: validation tests and simulation of an Atlantic cyclone and cold front." *Mon. Wea. Rev.* 121, pp.1493-1513.

32 Grell, G.A., J. Dudhia, and D.R. Stauffer, 1994. "A description of the Fifth Generation Penn State/NCAR Mesoscale Model (MM5)." NCAR Technical Note, NCAR TN-398-STR, 138 pp.

In addition to development of meteorological inputs for CMAQ and CAMx, MM5 was also used to develop meteorological inputs for the CALMET/CALPUFF modeling system. As discussed further in Section 6 of this review, CALMET/CALPUFF was used to determine whether a BART eligible source contributes to visibility impairment at a Class I area. Refer to Section 6 of this review for further information on the use of MM5 for BART modeling.

The CENRAP meteorological modeling used for input to photochemical modeling and emission processing was performed by the Iowa Department of Natural Resources (IDNR) and is described fully in the report entitled Meteorological Model Performance Evaluation of an Annual 2002 MM5 (version 3.6.3) Simulation (hereafter referred to as the Meteorological Model Performance Evaluation report) .[33]

4.5.2 Meteorological Modeling Domain and Vertical Layer Structure

In the IDNR 36-km meteorological modeling, MM5 was configured to run on the standard continental-scale Regional Planning Organization (RPO) National Grid with 36-km grid point spacing. The RPO National Grid is defined on a Lambert conformal projection, with true latitudes at 33°N and 45°N, and the central latitude and longitude at 40°N and 97°W, respectively. The grid point spacing is 36-km. The continental expanse of this domain results in a grid of 165 (east-west) by 129 (north-south) dot points, and 164 (east-west) by 128 (north-south) cross points. Overall, the domain covers 5904 km by 4608 km. The MM5 domain provides overlap of the CMAQ and CAMx air quality modeling grid (described in section 3.3) to alleviate any numerical boundary artifacts that may be present in the MM5 output fields. Meteorology modeling was also completed on a regional-scale domain with 12 km grid spacing covering the central states by EPA Region VII and the Texas Commission on Environmental Quality to examine model prediction sensitivity to grid resolution. The vertical layer structure of the CENRAP meteorological modeling domain consists of 34 layers, a top level at 100 millibars, and increasing layer thickness with altitude. The vertical layer structure is further detailed in the Modeling Protocol.

4.5.3 Model Configuration

The final CENRAP MM5 modeling system configuration for the 2002 annual simulation is provided in the Modeling Protocol and the Meteorological Model Performance Evaluation report. Early MM5 simulations by the State of Iowa and the Lake Michigan Air Directors Consortium (LADCO) and further sensitivity tests were performed to identify an MM5 configuration for annual runs.

The initial 2002 36-km IDNR simulation results showed that MM5 results showed an extreme cold bias over the central U.S and unnatural diurnal profiles near shorelines. A number of sensitivity tests were performed by IDNR to resolve performance issues identified in the initial simulation. At the same time, sensitivity tests were performed in support of the development of

[33] Johnson, M. 2007. Meteorological Model Performance Evaluation of an Annual 2002\ MM5 (version 3.6.3) Simulation. Iowa Department of Natural Resources, Air Quality Bureau. (http://www.iowadnr.gov/air/prof/progdev/files/IDNR.2002mm5v363.evaluation.v204.p f)

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meteorological modeling for VISTAS.[34] The combination of all of these studies led to the configuration used by CENRAP for MM5 modeling detailed in the CENRAP TSD and the Modeling Protocol.

4.5.4 MM5 Processing and Application

Several preprocessing steps are necessary to prepare input data for an MM5 simulation. The MM5 modeling system provides all of the tools necessary to prepare topographic, vegetative, initial condition, boundary condition, and FDDA nudging input files.

Global topographic data at 2-minute (latitude/longitude) resolution were used to define terrain elevations on the 36-km grid. Land use distribution on the MM5 domains was defined from the 24-category USGS vegetation data with a resolution of 2 minutes.

The 3-hour Eta analysis and surface fields available from the National Center for Atmospheric Research (NCAR) were taken from the Eta Data Assimilation System (EDAS) and used to supply initial and boundary conditions to MM5, and for analysis nudging in the FDDA package. The EDAS analyses are developed from a wide variety of observational sources, including standard surface and upper air measurements, profiler networks, radar- and satellite-derived measurements, and ship and aircraft reports. The wide array of data sources, coupled with the high time- and spatial resolution provided by EDAS, result in an analysis product that far exceeds the level of detail found in traditional global-scale analyses.

Sea surface temperatures (SSTs) were approximated by ETA skin temperatures
The annual simulation was generated from 95 independent simulations initialized at 12Z and integrated through five days. To allow for approximately a two week photochemical model spin-up period, the simulation started at 12/16/2001 12Z.

4.5.5 Model Performance

Model performance evaluation was performed by IDNR through comparison with observations of surface and upper-air meteorological conditions and precipitation.[35] Additional performance evaluation was done by CENRAP by comparing the 2002 CENRAP MM5 simulation with the 2002 VISTAS MM5 and the interim 2002 WRAP simulations.[36] Details on this comparison can be found in the CENRAP TSD, Appendix A.

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[34] Olerud, D., Sims, A., 2004. MM5 2002 Modeling in Support of VISTAS (Visibility Improvement—State and Tribal Association). Baron Advanced Meteorological Systems, LLC, Research Triangle Park, NC. http://www.baronams.com/projects/VISTAS/reports/VISTAS_TASK3f_final.pdf

[35] Johnson, M. 2007. Meteorological Model Performance Evaluation of an Annual 2002\ MM5 (version 3.6.3) Simulation. Iowa Department of Natural Resources, Air Quality Bureau. (http://www.iowadnr.gov/air/prof/progdev/files/IDNR.2002mm5v363.evaluation.v204.pdf)

[36] Kemball-Cook, S., Y. Jia, C. Emery, R. Morris, Z. Wang and G. Tonnesen, 2005. *Comparison of CENRAP, VISTAS and WRAP 36 km MM5 Model Runs for 2002, Task 3: Met Gatekeeper Report.* http://pah.cert.ucr.edu/aqm/cenrap/ppt_files/CENRAP_VISTAS_WRAP_2002_36km_MM5_eval.ppt

The goal of the evaluation was to determine whether the meteorological fields are sufficiently accurate to properly characterize the transport, chemistry, and removal processes in CMAQ/CAMx. If errors in the meteorological fields are too large, the ability of the air quality model to replicate regional pollutant levels over the entire base year will be severely hampered and the predicted impacts from future year growth and controls will be highly questionable. To provide a reasonable meteorological characterization to the photochemical/visibility model, MM5 must represent with some fidelity the:

- Large-scale weather patterns (i.e., synoptic patterns depicted in the 850-300 mb height fields), as these are key forcings for mesoscale circulations;
- Mesoscale and regional wind, temperature, PBL height, humidity, and cloud/precipitation patterns;
- Mesoscale circulations such as sea breezes and mountain/drainage circulations;
- Diurnal cycles in PBL depth, temperature, and humidity.

For visibility applications, the moisture and condensate fields are particularly important as they significantly impact PM chemical formation, removal, and light scattering efficiency. In addition, cloud and precipitation fields are a good measure of the integrated performance of the model since these are model-derived quantities and not nudged to observations. Because of the model's coarse resolution of 36-km, the model cannot be expected to faithfully simulate the pattern or variability of the convective precipitation, but should reproduce the synoptic precipitation and cloud patterns.

The IDNR evaluation of the MM5 model performance was limited to operational testing of the model, and not to a scientific evaluation. Previous peer-reviewed documentation of MM5 formulation, testing, and evaluation provide the basis for its scientific validity. An operational evaluation entails an assessment of the model's ability to correctly estimate surface and boundary layer wind, temperature, and moisture largely independent of whether the actual process descriptions in the model are accurate. The operational evaluation essentially tests whether the predicted meteorological fields are reasonable, consistent, and agree adequately with available observations in time and space. The process provides only limited information about whether the results are correct from a scientific perspective or whether they are the fortuitous product of compensating errors; thus a "successful" operational evaluation is a necessary but insufficient condition for achieving a sound, reliable performance testing exercise.

The basis for the IDNR operational performance assessment entailed a comparison of the predicted meteorological fields to available surface and aloft data that are collected, analyzed, and disseminated by the National Weather Service. It was carried out both graphically and statistically to evaluate model performance for winds, temperatures, humidity, and the placement, intensity, and evolution of key weather phenomena. The MM5 results were compared to a specific set of statistics that have been identified for use in establishing benchmarks for acceptable MM5 model performance.[37] The IDNR concluded, based on the

[37] Emery, C.A., E. Tai, and G. Yarwood. 2001. "Enhanced meteorological modeling and performance evaluation for two Texas ozone episodes." Prepared for the Texas Natural Resource Conservation Commission, by ENVIRON International Corporation.

results of the performance evaluation, that the final 36 km CENRAP MM5 simulations exhibit reasonably good performance for the central U.S.

Comparison of CENRAP MM5 performance with similar modeling efforts by WRAP and VISTAS revealed comparable performance across all three simulations. The three simulations showed similar performance for prediction of surface wind speed, wind direction and humidity. The use of surface data assimilation of temperature in the interim WRAP simulation resulted in the best performance in prediction of surface temperatures but the poorest performance for vertical temperature profiles. Surface data assimilation has since been dropped from the WRAP modeling protocol. The 2002 VISTAS MM5 simulations showed the best performance and the CENRAP performance more closely resembled that of the VISTAS than the WRAP.

The 2002 CENRAP MM5 model results are within the bounds of other meteorological databases used for prior air quality modeling efforts. It is therefore deemed reasonable to proceed with its use as inputs for visibility modeling. The EPA accepts the use of MM5 in this configuration and selected modeling domain and recognizes that the MM5 meteorological model used by CENRAP was state-of-the-science at the time the modeling was conducted. The performance of the model was adequate for the purposes for which it was used and on par with other studies at the time. A new meteorological model, the Weather Research Forecast model (WRF), has been developed to address the some of the limitations of the MM5 model and should be considered as a possible alternative for future meteorological modeling efforts.

4.6 SMOKE EMISSIONS MODEL

CENRAP selected the Sparse Matrix Operator Kernel Emissions model[38] to generate gridded hourly speciated emission estimates for mobile, non-road, area, point, fire and biogenic emission sources for use as inputs for photochemical grid models. The purpose of SMOKE is to convert the spatial and temporal resolution of the available emission inventory data to the resolution needed by the air quality model. SMOKE also has the ability to compute emissions for mobile on-road and biogenic sources. Biogenic emission modeling is performed through SMOKE with the Biogenic Emission Inventory System, version 3 (BEIS3)[39] using the Biogenic Emissions Landcover Database (BELD3) vegetative database. Mobile emissions can be calculated by SMOKE from mobile-source activity data, using emission factors from the MOBILE6 model. SMOKE supports the emission input formats required by the CAMX and CMAQ air quality models.

4.7 AIR QUALITY MODEL

Photochemical air quality models offer opportunity to better understand the sources of particulate matter that impair visibility by simulating the emissions, formation, transport, and deposition of these pollutants. If an air quality model performs well for a historical episode, the model may then be useful for identifying the sources of particulate matter and helping to select the most effective emissions reduction strategies for attaining visibility goals. Although several types of air quality modeling systems are available, the gridded, three-dimensional, Eulerian models provide the most complete spatial representation and the most comprehensive representation of

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[38] Available at http://www.smoke-model.org/index.cfm
[39] Available at http://www.epa.gov/ttn/chief/software.html#pcbeis

processes affecting particulate matter, especially for situations in which multiple pollutant sources interact to form particulate matter.

4.7.1 Model Selection

Guidance from the EPA requires that the air quality model should be selected based on intended application and must be freely downloadable to all stakeholders. Furthermore, the user must be able to revise the code to perform diagnostic analyses and/or to improve the model's ability to describe observations in a credible manner. Several additional prerequisites should be met for a model to be used to support an attainment demonstration or uniform rate of progress assessment.

- It should have received and been revised in response to a scientific peer review.
- It should be appropriate for the specific application on a theoretical basis.
- It should be used with a data base which is adequate to support its application.
- It should be shown to have performed well in past modeling applications. (If the application is the first for a particular model, then the State should note why it believes the new model is expected to perform sufficiently.)
- It should be applied consistently with a protocol on methods and procedures.

The Guideline on Air Quality Models (GAQM - 40 CFR Part 51 Appendix W) does not indicate a preferred photochemical grid model for Regional Haze applications. The CMAQ and CAMx models have been accepted by EPA for numerous regulatory air quality modeling applications and were considered by CENRAP for use in regional haze modeling. CENRAP selected CMAQ Version 4.5 with "SOAmod enhancements" as the primary air quality model for regional haze modeling and the CAMx Version 4.40 model, applied using similar options as used by CMAQ, as a secondary corroborative model. CAMx was also utilized with its Particulate Source Apportionment Technology (PSAT) tool to provide source apportionment with both the baseline and future case emissions inventories (See Section 5). EPA concurred with the selection of CAMx for the CENRAP regional haze modeling as it has been extensively used within the region and has been proven to be an acceptable model. The selection of CMAQ was based on review of previous and concurrent studies within CENRAP and other RPOs, as well as comparisons with CAMx model results.[40] Major differences between the two models that still exist are in the basic model code, in the treatment of horizontal diffusion SOA formation mechanisms, and in grid nesting. EPA accepts the choice of CMAQ as it satisfies the requirements and guidelines detailed above. The versions of CMAQ and CAMx used by CENRAP in its visibility modeling were the state-of-the-science at the time they were implemented and are acceptable to EPA for this Regional Haze selection.

Both air quality models were set up and run on the RPO national 36–km modeling domain described in section 3.3. This modeling domain is also used by WRAP and VISTAS. Sensitivity runs performed by CENRAP for CMAQ run on a 12km modeling domain revealed limited improvement over the 36-km runs and a large increase in computer resources and time. CAMx runs at 12-km resolution reduced the sulfate under-prediction bias in the summertime when

[40] Morris, R.E., et al. 2006. CENRAP Modeling Update: CMAQ versus CAMx Model Performance Evaluation. Presented at CENRAP Modeling Work Group Meeting, Baton Rouge, Louisiana. (http://pah.cert.ucr.edu/aqm/cenrap/ppt_files/ Morris_MPE_Feb6-8_2006.ppt)

compared to 36-km runs. With this possible exception, CENRAP noted little benefit in overall model performance with use of the 12-km grid. Therefore, the 36km domain was selected for all CENRAP CMAQ and CAMx runs.[41]

These air quality models are discussed in more detail below.

4.7.1.1 CMAQ Air Quality Model

EPA initially developed the Community Multi-Scale Air Quality (CMAQ) modeling system in the late 1990s. The model source code and supporting data can be downloaded from the Community Modeling and Analysis System (CMAS) Center (http://www.cmascenter.org/), which is funded by EPA to distribute and provide limited support for CMAQ users. CMAQ was designed as a "one atmosphere" modeling system to encompass modeling of multiple pollutants and issues, including ozone, PM, visibility, and air toxics. This is in contrast to many earlier air quality models that focused on single-pollutant issues (e.g., ozone modeling by the Urban Airshed Model). CMAQ is an Eulerian model—that is, it is a grid-based model in which the frame of reference is a fixed, three-dimensional (3-D) grid with uniformly sized horizontal grid cells and variable vertical layer thicknesses. The number and size of grid cells and the number and thicknesses of layers are defined by the user, based in part on the size of the modeling domain to be used for each modeling project. The key science processes included in CMAQ are emissions, advection and dispersion, photochemical transformation, aerosol thermodynamics and phase transfer, aqueous chemistry, and wet and dry deposition of trace species. CMAQ offers a variety of choices in the numerical algorithms for treating many of these processes, and it is designed so that new algorithms can be included in the model. CMAQ offers a choice of three photochemical mechanisms for solving gas-phase chemistry: the Regional Acid Deposition Mechanism version 2 (RADM2), a fixed coefficient version of the SAPRC90 mechanism, and the Carbon Bond IV mechanism (CB-IV).

CENRAP used CMAQ Version 4.5 with a "SOAmods enhancement" for 2002 base case (actual emissions), 2002 baseline (typical emissions) and 2018 future case (projected emissions) modeling. The "SOAmods enhancement" was the result of work by VISTAS investigating the model's underestimate of organic mass carbon (OMC) concentrations. The updated CMAQ secondary organic aerosol (SOA) module led to improved estimation of OMC in VISTA modeling. CENRAP examined the use of the enhanced SOA module and found similar improvements in model performance over the original CMAQ Version 4.5 model. CENRAP decided to use the CMAQ Version 4.5 with the "SOAmods enhancement"[42] for CENRAP modeling. Details of the CMAQ model configuration used by CENRAP can be found in the CENRAP TSD and the Modeling Protocol.

4.7.1.2 CAMx Air Quality Model

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[41] Morris, R.E., et al. 2006. CENRAP Modeling: Need for 36 km versus 12 km Grid Resolution. Presented at CENRAP Modeling Work Group Meeting, Baton Rouge, Louisiana. (http://pah.cert.ucr.edu/aqm/cenrap/ppt_files/ Morris_36vs12km_Feb6-8_2006.ppt)

[42] Morris, R.E., B. Koo, A. Guenther, G. Yarwood, D. McNally, T.W. Tesche, G. Tonnesen, J. Boylan and P. Brewer. 2006. Model Sensitivity Evaluation for Organic Carbon using Two MultiPollutant Air Quality Models that Simulate Regional Haze in the Southeastern United States. Atmos. Env. 40 (2006) 4960-4972.

The Comprehensive Air Quality Model with extensions (CAMx) model[43] was initially developed by ENVIRON in the late 1990s as a nested-grid, gas-phase, Eulerian photochemical grid model. ENVIRON later revised CAMx to treat PM, visibility, and air toxics. While there are many similarities between the CMAQ and CAMx systems, there are also some significant differences in their treatment of advection, dispersion, aerosol formation, and dry and wet deposition. CAMx has seen extensive use within many of the CENRAP states. The CAMx model is based on well-established treatments of advection, diffusion, deposition, and chemistry. CENRAP used CAMx Version 4.40, applied using similar options as used by CMAQ, as a secondary corroborative model and utilized CAMx with its Particulate Source Apportionment Technology (PSAT) tool to provide source apportionment of nitrate and sulfate aerosol with both the 2002 baseline and 2018 future case emission inventories (See section 5). Details of the CAMx model configuration used by CENRAP can be found in the CENRAP TSD and the Modeling Protocol.

4.7.2 Vertical Modeling Domain

CMAQ and CAMx have the ability to collapse the 34 layer vertical structure used in MM5 modeling to a smaller set of vertical layers. Sensitivity studies by WRAP and VISTAS examined model performance looking at a variety of vertical modeling domains ranging from modeling all 34 vertical layers to collapsing the structure down to 12 vertical layers. Results of this study showed that collapsing the vertical structure down to 19 layers while matching the 8 bottom most vertical layers produced results nearly identical to the full 34 layer runs. The more aggressive layer collapsing scheme of 12 layers produced substantially different results. Based on these results, CENRAP selected the 19 layer vertical structure described in the CENRAP TSD. This selection improves computational efficiency and produces results almost identical to the full vertical structure runs.

4.7.3 Initial and Boundary Conditions

Initial conditions (ICs) are specified by the user for the first day of a model simulation. For continental-scale modeling using the RPO 36-km domain, the ICs can affect model results for as many as 15 days, although the effect typically becomes very small after about 7 days. A model spin-up period is included in each simulation to eliminate any effects from the ICs. For the CENRAP modeling, the annual simulation is divided into four quarters, and included a 15-day spin-up period for the quarters beginning in April, July, and October. For the quarter beginning in January 2002, a spin-up period covering December 16-31, 2001, using meteorology and emissions data developed for CENRAP were used. We agree that the 15 day spin-up period employed by CENRAP was sufficient to minimize the effects of the IC on model results given the size of the modeling domain.

Boundary conditions (BCs) specify the concentrations of gas and PM species at the four lateral boundaries of the model domain. BCs determine the amounts of gas and PM species that are transported into the model domain when winds flow into the domain. Boundary conditions have a much larger effect on model simulations than do ICs. For some areas in the CENRAP region and for clean conditions, the BCs can be a substantial contributor to visibility impairment. For this study BC data generated in an annual simulation of the global-scale GEOS-Chem model for

[43] ENVIRON, 2006. "User's Guide – Comprehensive Air-quality Model with extensions, Version 4.30." ENVIRON International Corporation, Novato, California. (available at http://www.camx.com).

calendar year 2002 were applied.[44] The BCs employed by CENRAP were state-of-the-science at the time they were implemented.

4.7.4 Base Case/ Baseline Model Performance

The 2002 Base Case modeling efforts were used to evaluate air quality/visibility modeling systems for a historical episode—in this case, for calendar year 2002—to demonstrate the suitability of the modeling systems for subsequent planning, sensitivity, and emissions control strategy modeling. Comparisons between the 2002 Base F actual emissions model performance with the 2002 typical emissions (Typ02F) revealed little difference in model performance. The 2002 F model predictions are nearly identical to 2002 G results so model performance evaluation performed with 2002 Base F emissions is representative of the final model performance. Therefore, model performance was evaluated using the Typ02F emission inventory.

Model performance evaluation is performed by comparing output from model simulations with ambient air quality data for the same time period to determine whether the model's performance is sufficiently accurate to justify using the model for simulating future conditions. There are a number of challenges in completing an annual MPE for regional haze. The model must be compared to ambient data from several different monitoring networks for both PM and gaseous species, for an annual time period, and for a large number of sites. The focus of the performance evaluation is on the six components of particulate matter that are used to characterize visibility at Class I areas: Sulfate (SO4); Particulate Nitrate (NO3); Elemental Carbon (EC); Organic Mass Carbon (OMC); Other inorganic fine particulate (IP or Soil); and Coarse Matter (CM). The model must be evaluated for both the worst visibility conditions and for very clean conditions. Finally, final guidance on how to perform an MPE for fine-particulate models is not available from EPA. Therefore, the CENRAP experimented with many different approaches for showing model performance results.

The plot types that were found to be the most useful are the following:

- Time-series plots comparing the measured and model-predicted species concentrations
- Scatter plots showing model predictions on the y-axis and ambient data on the x-axis
- Spatial analysis plots with ambient data overlaid on model predictions
- Bar plots comparing the mean fractional bias (MFB) or mean fractional error (MFE) performance metrics
- "Bugle plots" showing how model performance varies as a function of the PM species concentration
- Stacked-bar plots of contributions to light extinction for the average of the best-20% visibility days or the worst-20% visibility days at each site; the higher the light extinction, the lower the visibility

The following plots depict summary model performance for CENRAP CMAQ modeling using the Typ02F emissions inventory. Below are six sets of model fractional bias and model fractional error plots. Each set of plots compares the measured chemically speciated aerosol data

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[44] Jacob, D.J., R. Park and J.A. Logan. 2005. Documentation and Evaluation of the GEOS-CHEM Simulation for 2002 Provided to the VISTAS Group. Harvard University (http://www.vistas-sesarm.org/documents/Harvard_GEOS-CHEM_FinalReport_20050624.doc)

from a monitoring network with the corresponding model output. The monitoring networks used for comparison are IMPROVE, CASTNET, and STN, and are treated separately because each monitoring network has different goals, siting criteria, and data collection protocols. The model performance plots depicted here are "bugle plots", and depict model performance (symbols) and model performance standards (curves) on the y axis relative to measured concentration on the x axis. Model performance standards are of greater latitude at lower concentrations because of the higher relative uncertainties in the data at lower concentrations. Performance goals or criteria approach 200% error and ≤200% bias as observed concentrations approach zero and asymptotically approach the proposed performance goals or criteria (i.e., the ≤30%/50% and ≤60%/75% bias/error levels) as concentrations become greater than 2.5 $\mu g/m^3$.

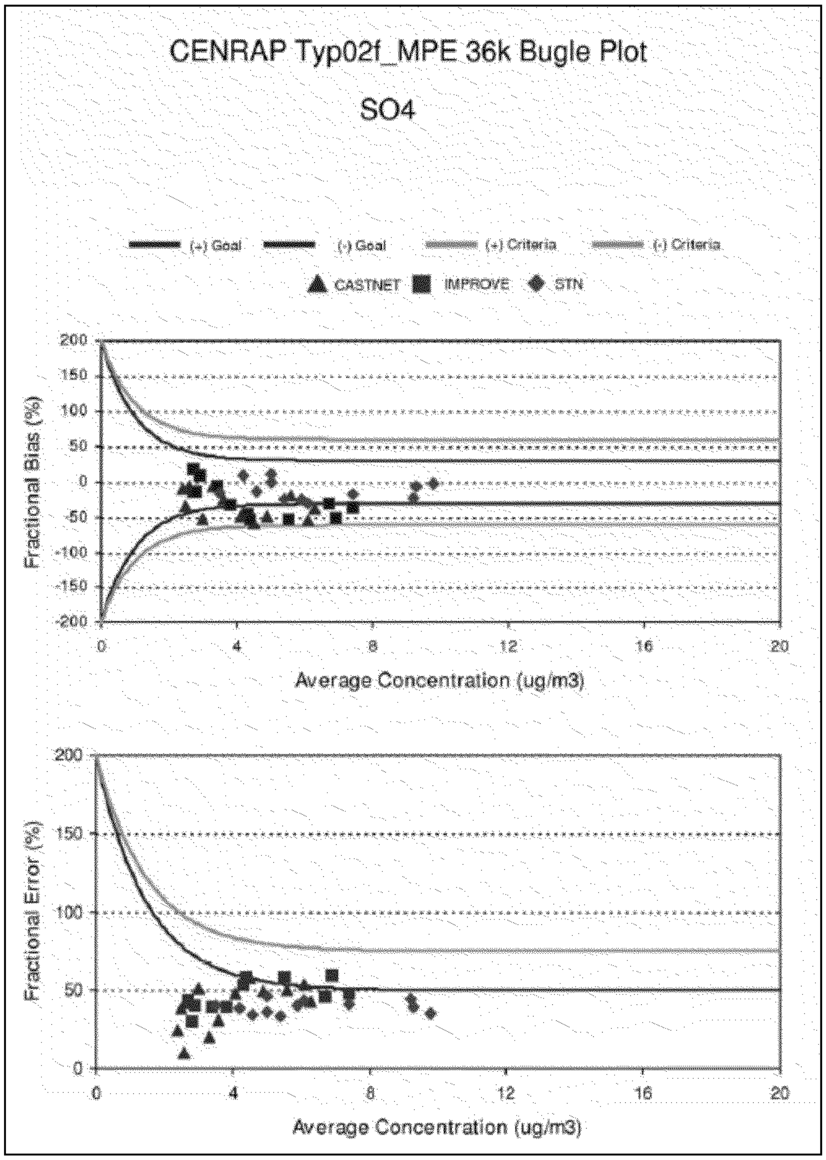
Model performance at IMPROVE monitors is of highest importance, because these monitors are sited to be representative of the visibility conditions impacting each Class 1 Area. The CASTNET monitoring network is more sparse than the IMPROVE network, but is also mostly sited at Class 1 Areas and as such, model performance at CASTNET sites should also be considered important. The STN monitoring network is an urban network, and model performance relative to this network should be given less importance.

The model performance goals and criteria used by CENRAP were appropriate at the time the modeling was conducted and consistent with the methods adopted by VISTAS and WRAP. The EPA agrees with the CENRAP model performance procedures and analysis. Detailed results of the model performance evaluation can be found in Appendix C of the CENRAP TSD and on the University of California, Riverside CENRAP visibility modeling website (http://pah.cert.ucr.edu/aqm/cenrap/cmaq.shtml#cmaq_typ02f_mpe).

4.7.4.1 Model Performance for Sulfate (SO_4)

Figure 4-2 shows the monthly SO_4 fractional error and bias for the STN, IMPROVE and CASTNET monitoring networks as well as the proposed performance goals and criteria. In general, there is an under-prediction bias that is more pronounced during the spring and summer months. For the STN network, model performance for all months is within the goals for both fractional bias and error. Model performance for CASTNET sites is within goals for fractional error and within the criteria for fractional bias as is model performance for the IMPROVE sites with the exception of two months that lie within the criteria but beyond the goal for fractional error.

Figure 4-2. CENRAP model performance (factional bias and error) of the Typ02f modeling scenario for sulfate (SO_4). The 12 symbols for each monitor represent monthly average model performance for the year 2002, averaging all monitors in the CENRAP region. Solid lines represent CENRAP modeling goals and criteria.

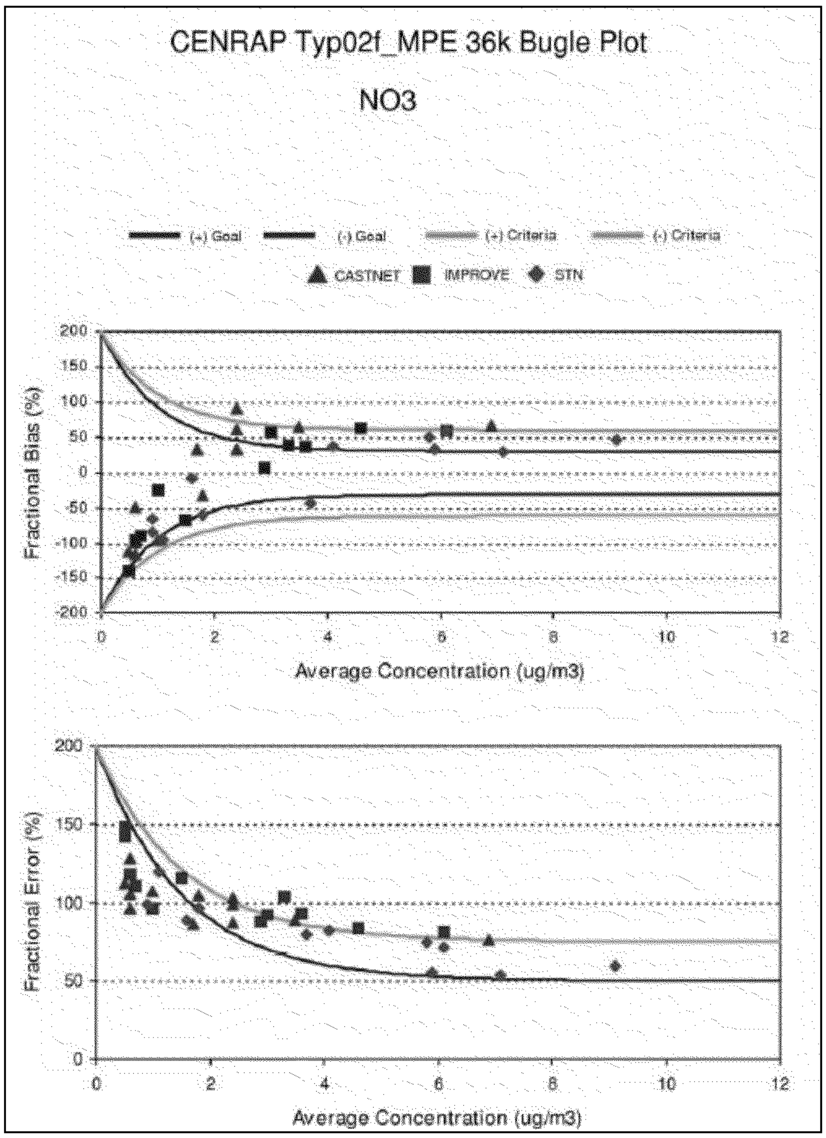


4.7.4.2 Model Performance for Nitrate (NO_3)

Figure 4-3 shows the monthly NO_3 fractional error and bias for the STN, IMPROVE and CASTNET monitoring networks as well as the proposed performance goals and criteria. NO3 model performance is variable. There is an underprediction during the summer months, approaching a fractional bias of -140% in June and July and an overprediction with bias of approximately 50% in the winter. The winter bias is more significant because NO_3 concentrations tend to be a large component of visibility impairment during the winter months.

In general, winter model performance does not meet the performance goals and in some cases does not meet the criteria, predicting concentrations of NO_3 much higher than observed.

Figure 4-3. CENRAP model performance (factional bias and error) of the Typ02f modeling scenario for nitrate (NO_3). The 12 symbols for each monitor represent monthly average model performance for the year 2002, averaging all monitors in the CENRAP region. Solid lines represent CENRAP modeling goals and criteria.

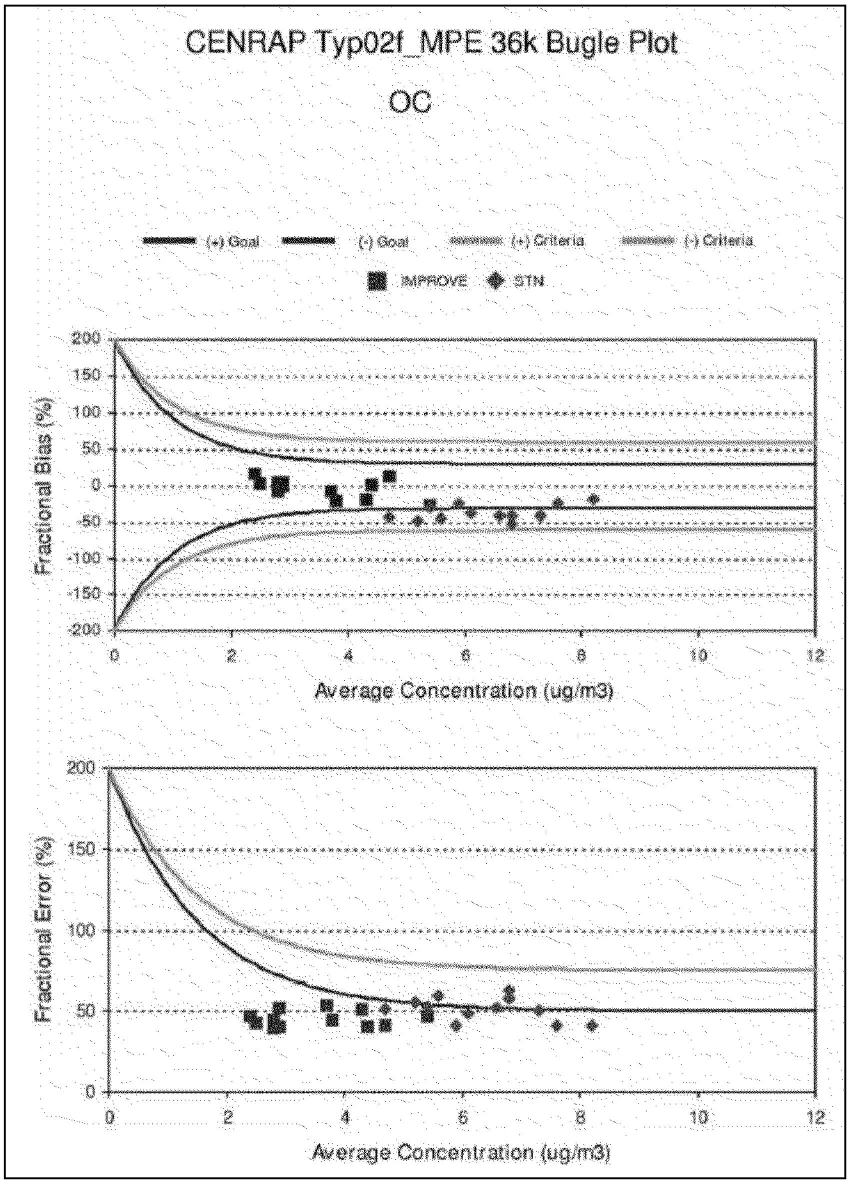


4.7.4.3 Model Performance for Organic Carbon (OC)

Figure 4-4 shows the monthly OC fractional error and bias for the STN and IMPROVE monitoring networks as well as the proposed performance goals and criteria. For the IMPROVE network, model performance for all months is within the goals for both fractional bias and error. The STN monitors in urban areas measured higher concentrations of OC then the rural

IMPROVE monitors. Model performance for STN sites shows a negative bias throughout the year that fall within the model criteria for both bias and error.

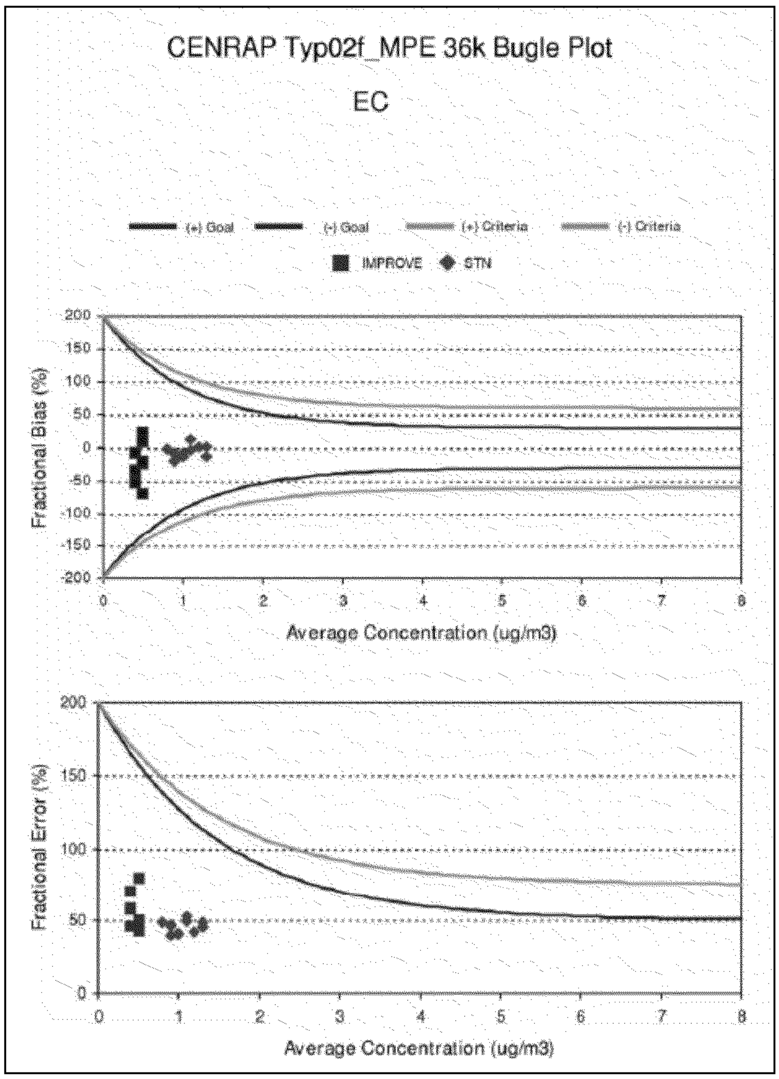
Figure 4-4. CENRAP model performance (factional bias and error) of the Typ02f modeling scenario for organic carbon (OC). The 12 symbols for each monitor represent monthly average model performance for the year 2002, averaging all monitors in the CENRAP region. Solid lines represent CENRAP modeling goals and criteria.



4.7.4.4 Model Performance for Elemental Carbon (EC)

Figure 4-5 shows the monthly EC fractional error and bias for the STN and IMPROVE monitoring networks as well as the proposed performance goals and criteria. Model performance for EC falls within the proposed performance goals. Fractional bias for the STN sites is small with a fractional error around 50%. There is a large model underprediction during the summer at the IMPROVE sites. However, EC concentrations at these sites are low putting the model performance within the goals for low concentrations.

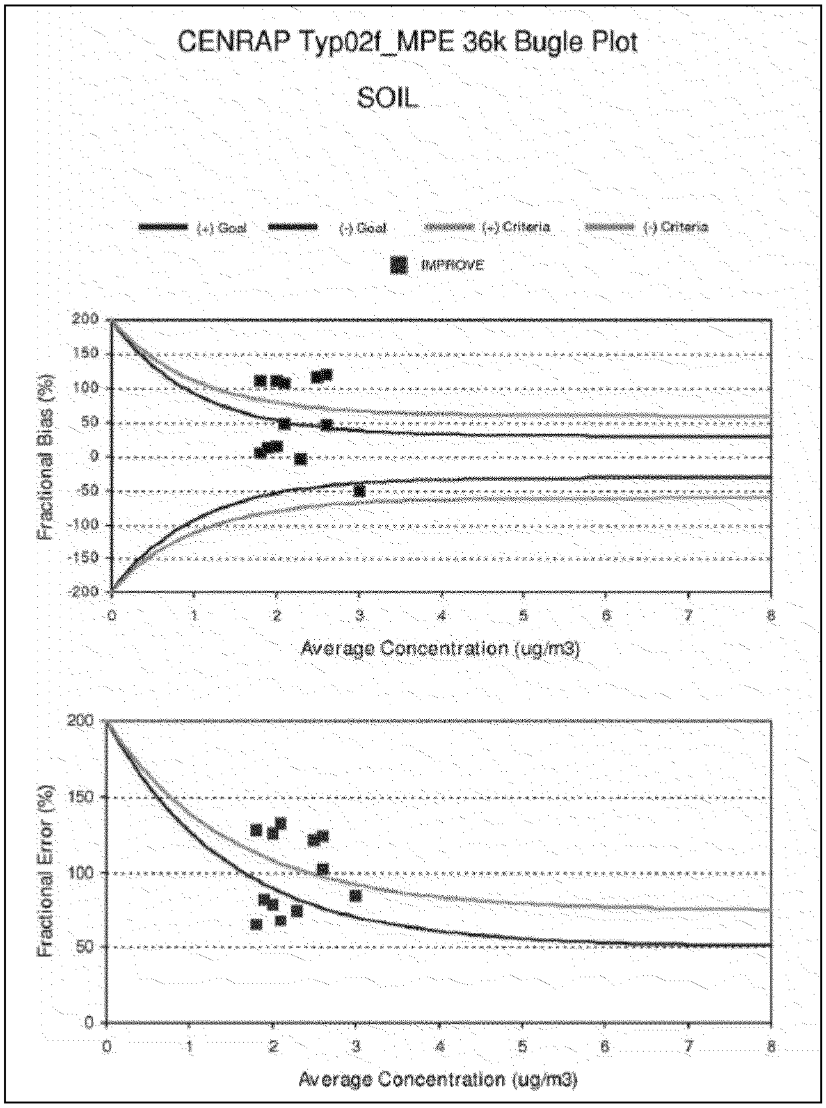
Figure 4-5. CENRAP model performance (factional bias and error) of the Typ02f modeling scenario for elemental carbon (EC). The 12 symbols for each monitor represent monthly average model performance for the year 2002, averaging all monitors in the CENRAP region. Solid lines represent CENRAP modeling goals and criteria.



4.7.4.5 Model Performance for Soil

Figure 4-6 shows the monthly soil fractional error and bias for the monitoring network as well as the proposed performance goals and criteria. Model performance for the winter months is poor with large overpredictions of soil concentrations. The summer months are within the goals for both fractional bias and error with performance getting worse in the fall and spring. This may be due to local effects near the monitor and difficulties in capturing emissions accurately in the inventory. This is an area of concern, especially in areas where soil contributes significantly to visibility impairment.

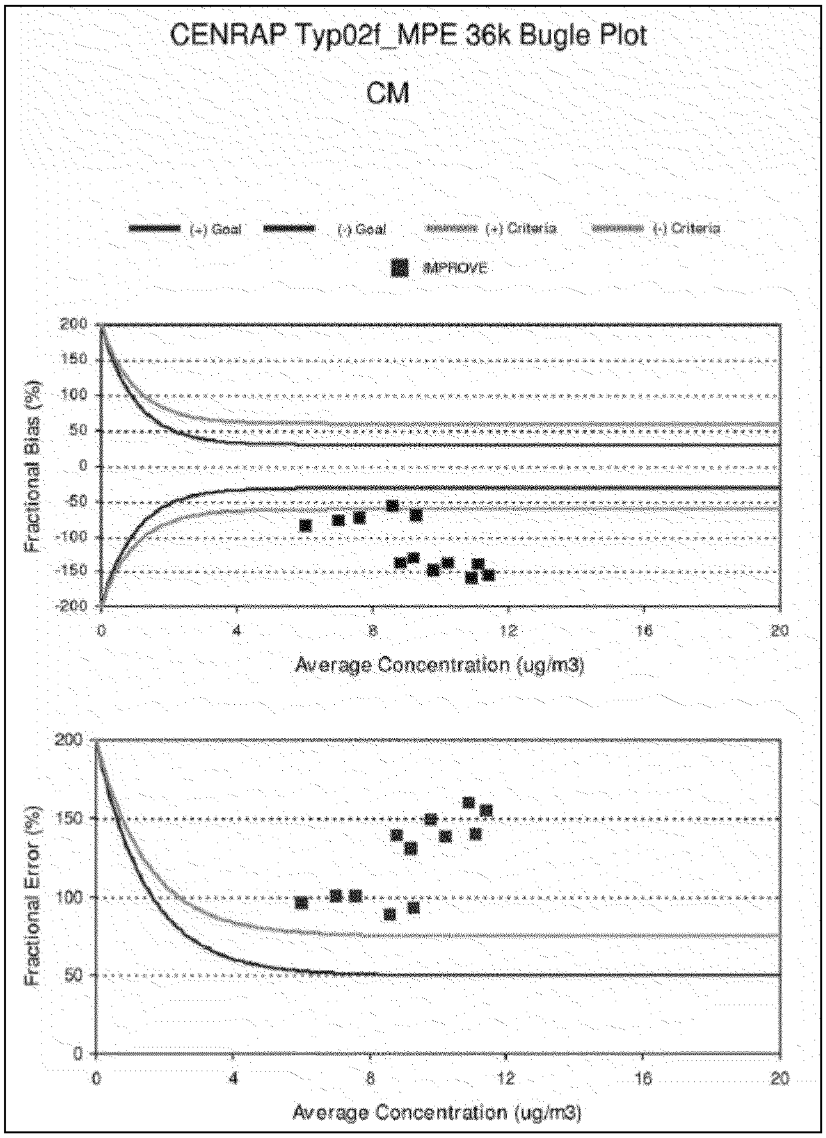
Figure 4-6. CENRAP model performance (factional bias and error) of the Typ02f modeling scenario for soil. The 12 symbols for each monitor represent monthly average model performance for the year 2002, averaging all monitors in the CENRAP region. Solid lines represent CENRAP modeling goals and criteria.



4.7.4.6 Model Performance for Course Particulate Material (CM)

Figure 4-7 shows the monthly CM fractional error and bias for IMPROVE and monitoring network as well as the proposed performance goals and criteria. Model performance is poor with large underpredictions of CM concentrations throughout the year. This may be due to localized emissions near the monitor and difficulties in capturing these emissions accurately in the inventory. This is an area of concern, especially in areas where CM contributes significantly to visibility impairment.

Figure 4-7. CENRAP model performance (factional bias and error) of the Typ02f modeling scenario for course particulate material (CM). The 12 symbols for each monitor represent monthly average model performance for the year 2002, averaging all monitors in the CENRAP region. Solid lines represent CENRAP modeling goals and criteria.



4.7.4.7 Model Performance for Prediction of Total Extinction

The above model performance summary includes all sites within the CENRAP. However, a model performance summary over such a diverse geographic area may mask model performance issues occurring in smaller geographic sub-regions. CENRAP also evaluated model performance in predicting total extinction on the 20% best and 20% worst days at each Class I site. Performance for the worst 20% days at the CENRAP Class I areas is generally characterized by an underestimation bias. Performance at the Breton Island (BRET), LA, Big Bend (BIBE), TX and Guadalupe Mountains (GUMO), TX Class I areas for the worst 20 percent days is particularly poor. At GUMO, visibility impairment is primarily due to high soil and CM which are not well predicted by the model across the CENRAP area. At the BRET and BIBE sites, all components are under-predicted, leading to an under-prediction in total extinction. Model predictions at these sites are less reliable than at other CENRAP sites for planning purposes. In general, model performance is acceptable for SO_4, NO_3, OMC and EC at the Class I areas. The model was not able to accurately predict CM and soil concentrations in the CENRAP region.

In order to address this model performance issue, CENRAP investigated the assumption that all CM and soil are natural and their concentrations remain constant for future projections as well as assuming that only a portion of the soil was from natural sources. Results of this sensitivity analysis showed that these various projections of CM and soil had little effect on visibility predictions at the CENRAP class I areas. See section 5.5.1 of the CENRAP TSD for results of this sensitivity analysis.

Within the state of Arkansas, the Caney Creek Wilderness Area and Upper Buffalo Wilderness Area are the only Class I areas. Model performance at predicting total extinction at Caney Creek and Upper Buffalo during the worst 20% and best 20% days are shown in Figures 4-8 and 4-9. On most of the worst 20 % days at Caney Creek, total extinction is dominated by sulfate extinction with some extinction due to OMC. On four of the worst 20% days extinction is dominated by nitrate. Sulfate is underestimated and results in an under-prediction (-33% bias) on total extinction. There is an overestimate of extinction (+44% bias) on the 20% best days due to an over-prediction of NO_3. For Upper Buffalo, the worst 20% days are dominated by sulfate extinction, however two of these worst days are dominated by nitrate. Sulfate and OMC under-prediction results in an under-prediction (-40%) on total extinction. Overall performance is good on the 20% best days at Upper Buffalo, however there are large over-predictions of nitrate on some days.

Figure 4-8. Daily extinction model performance at Caney Creek Wilderness Area AR for the worst (top) and best (bottom) 20% days during 2002.

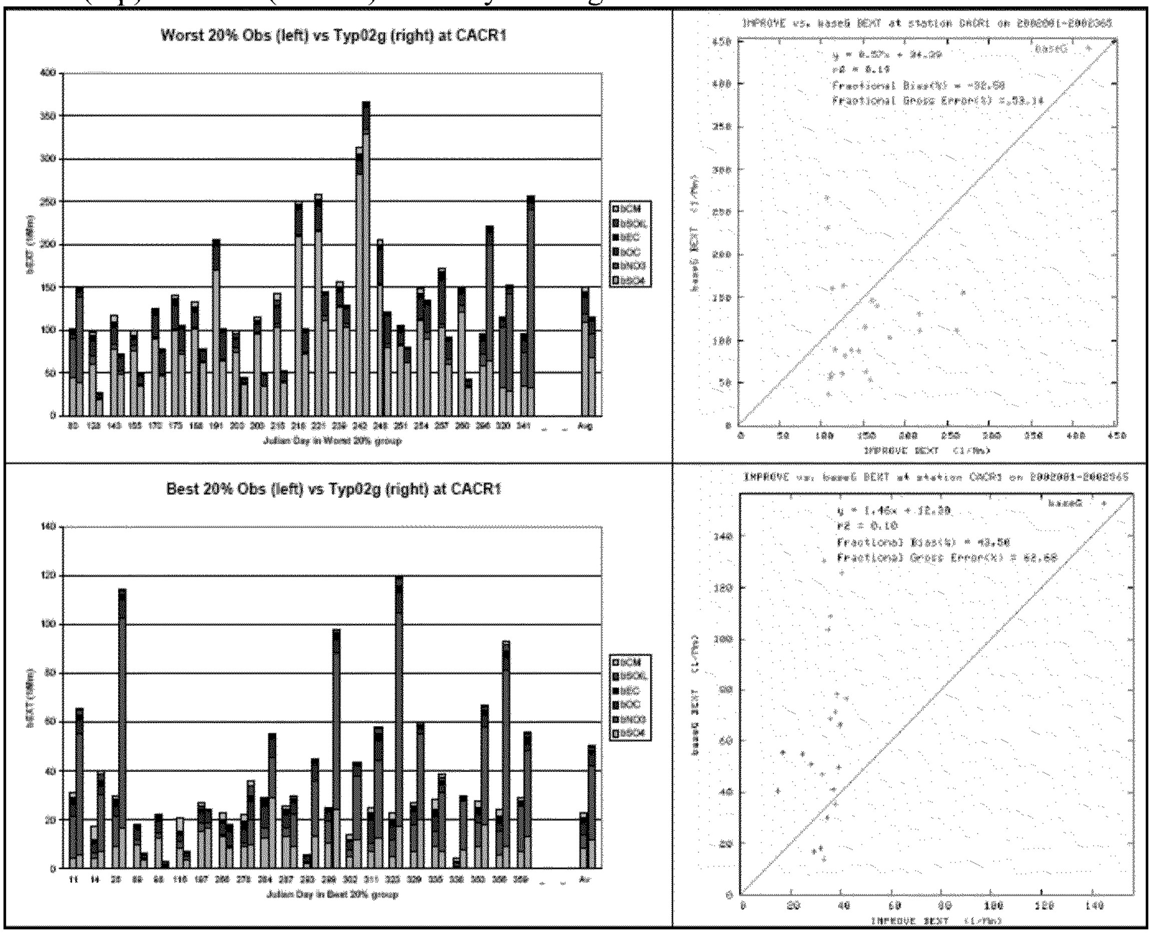
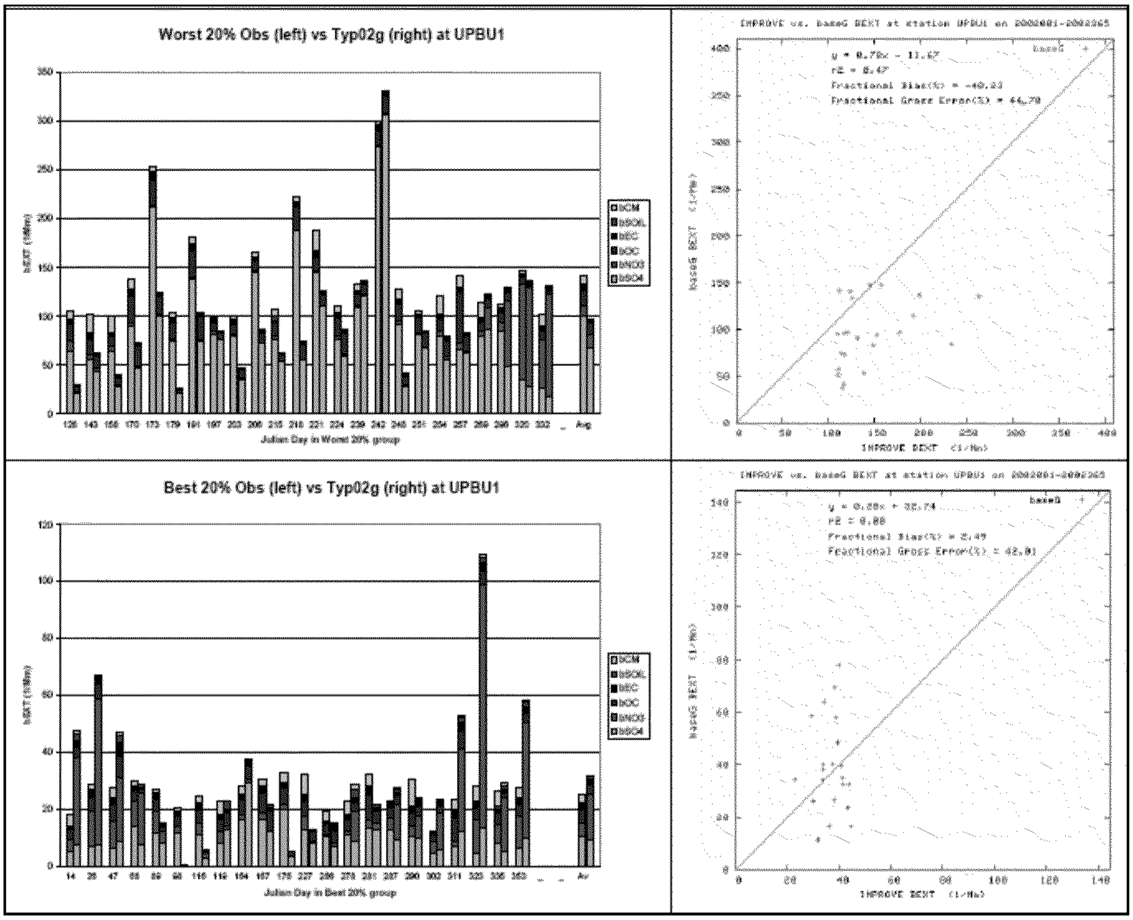


Figure 4-9. Daily extinction model performance at Upper Buffalo Wilderness Area, AR for the worst (top) and best (bottom) 20% days during 2002.



Chapter 5: 2018 Future Year Modeling

5.1 2018 Model Simulations

The 2018 future-year base case scenario is referred to as "2018 Base Case" or "Base18G". The purpose of the Base18G scenario is to simulate the air quality representative of conditions in future year 2018 with respect to sources of criteria and particulate matter air pollutants, taking into consideration growth and controls. Modeling results based on this emission inventory are used to define the future year ambient air quality and visibility metrics.

Input data used for the 2018 model simulations consisted of the same meteorology as for the 2002 Base Case and the Base18 emission inventories described under the Emissions Modeling section (Section 3). The setup of the CMAQ model (including science options, run scripts, simulation periods, and ancillary data) for the 2018 cases was identical to that used in the Typ02G modeling.

The purpose of modeling 2018 visibility is to compare the 2018 visibility predictions to the 2002 typical-year visibility modeling results and compare 2018 visibility predictions to the URP goal for 2018, as discussed below. Some improvements in visibility by 2018 are expected because of reductions in emissions due to currently planned regulations and technology improvements. The methodology used by CENRAP in developing visibility projections for 2018 and described below is consistent with EPA guidance.

5.2 Visibility Projections

The Regional Haze Rule (RHR) goals include achieving natural visibility conditions at 156 federally mandated Class I areas by 2064. In more specific terms, that RHR goal is defined as (1) visibility improvement toward natural conditions for the 20% of days that have the worst visibility (termed "20% worst" visibility days) and (2) no worsening in visibility for the 20% of days that have the best visibility ("20% best" visibility days). One component of the states' demonstration to EPA that they are making reasonable progress toward this 2064 goal is the comparison of modeled visibility projections for the first milestone year of 2018 with what is termed a uniform rate of progress (URP) goal. As explained in detail in Section 2, the 2018 URP goal is obtained by constructing a "linear glide path" (in deciviews) that has at one end the observed visibility conditions during the mandated five-year (2000-2004) baseline period and at the other end natural visibility conditions in 2064; the visibility value that occurs on the glide path at year 2018 is the URP goal.

CENRAP has made 2018 visibility projections using Typ02G and Base18G CMAQ 36-km modeling results following EPA guidance[45] that recommends applying the modeling results in a relative sense to project future-year visibility conditions. Projections are made using relative

[45] US EPA, 2006. Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze, US EPA, Office of Air Quality and Planning Standards, EPA-454/B-07-002, EPA, April 2007, (http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf)

response factors (RRFs), which are defined as the ratio of the future-year modeling results for each component that affects visibility to the current-year modeling results. The calculated RRFs are applied to the baseline observed visibility conditions to project future-year observed visibility. These projections can then be used to assess the effectiveness of the simulated emission control strategies that were included in the future-year modeling. The major features of our recommended visibility projections and guidance are as follows:

- Monitoring data should be used to define current air quality.
- Monitored concentrations of PM10 are divided into six major components; the first five are assumed to be PM2.5 and the sixth is PM2.5-10.
    - SO4 (sulfate)
    - NO3 (particulate nitrate)
    - OC (organic carbon)
    - EC (elemental carbon)
    - Soil (other fine particulate or soil)
    - CM (coarse matter).
- Models are used in a relative sense to develop RRFs between future and current predicted concentrations of each component.
- Component-specific RRFs are multiplied by current monitored values to estimate future component concentrations.
- Estimates of future component concentrations are consolidated to provide an estimate of future air quality.
- Future estimated air quality is compared with the goal for regional haze to see whether the simulated control strategy would result in the goal being met.

5.2.1 Mapping Model Results to IMPROVE Measurements

Each of the six PM components of light extinction in the revised IMPROVE mass extinction equation[46] is scaled separately. Because the modeled species do not exactly match up with the IMPROVE measured PM species, assumptions must be made to map the modeled PM species to the IMPROVE measured species for the purpose of projecting visibility improvements. Table 4-2 of the CENRAP TSD shows the assumptions used to relate modeled species in CMAQ Version 4.5 to the species used in the equation to estimate visibility. Some additional species (described in section 4.3.1 of the CENRAP TSD) resulting from the modified SOA module used by CENRAP are also included in the OC term.

5.2.2 Projecting Visibility Changes Using Modeling Results

RRFs are calculated as the ratio of the 2018 modeling results to the 2002 modeling results, and are specific to each Class I area and each PM species. These RRFs are applied to the baseline period visibility conditions calculated from observed PM species levels to project future-year PM levels. The projected PM levels are used to estimate visibility conditions in 2018 through the

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[46] IMPROVE technical subcommittee for algorithm review, 2006. Revised IMPROVE Algorithm for Estimating Light Extinction from Particle Speciation Data. (http://vista.cira.colostate.edu/improve/Publications/GrayLit/019_RevisedIMPROVEeq/RevisedIMPROVEAlgorithm3.doc)

revised IMPROVE equation. The following six steps found in the modeling guidance[47] summarize the general procedure used to project future-year visibility for the 20% best and 20% worst visibility days:

1) For each Class I area, rank visibility (in deciviews) on each day with observed speciated PM data for each of the 5 years of the base period.
2) For each of the 5 years comprising the base period, calculate the mean deciviews for the 20% worst and 20% best visibility days. For each Class I area, calculate the 5 year mean deciviews for the worst and best days from the 5 year-specific values.
3) Use an air quality model to simulate base period emissions and future emissions. Use the resulting information to develop relative response factors for each component of particulate matter identified in the IMPROVE equation.
4) Multiply the relative response factors times the measured species concentration data during the base period (for the 20% best and worst days). This results in daily future year species concentrations data.
5) Using the results in Step 4 and the IMPROVE algorithm calculate the future daily extinction coefficients for the 20% best and worst visibility days in each of the five base years.
6) Calculate daily deciview values (from total daily extinction) and then compute the future average mean deciviews for the best and worst days of each year. Then average the 5 years together to get the final future mean deciview value for the best and worst days.

The six steps listed above from national EPA modeling guidance for regional haze were followed by CENRAP to estimate projected future visibility conditions. These methods were appropriate at the time the modeling was performed.

5.3 REASONABLE PROGRESS GOAL AND PATH TO NATURAL CONDITIONS

A linear URP from the Baseline Conditions in 2004 to Natural Conditions in 2064 is assumed, and the value on the glide path at 2018 is the presumptive URP visibility target that the modeled 2018 projections are compared against to judge progress. The estimated visibility impairment in 2018 is less than the calculated URP for 2018 (Section 2). The URP acts as a benchmark for evaluating the reasonable progress towards reaching natural conditions by 2064.

In determining reasonable progress, section 169A(g) of the Clean Air Act requires that four factors be considered:

- Cost of compliance
- Time necessary for compliance
- Energy and non-air quality environmental impacts of compliance
- Remaining useful life of existing sources that contribute to visibility impairment.

Table 5-1 and figures 5-1 and 5-2 compares the URP using the natural conditions described in section 2 to the modeled visibility conditions in 2018 for each Class I area. For Caney Creek, the

[47] US EPA, 2006. Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze, US EPA, Office of Air Quality and Planning Standards, EPA-454/B-07-002, EPA, April 2007, (http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf)

baseline visibility (2002-2004) is 26.36 dv, and the estimated 2018 URP is 22.91dv. The modeling predicts a visibility improvement of 3.88dv by 2018, compared to the URP improvement of 3.45dv by 2018. For Upper Buffalo, the baseline visibility (2002-2004) is 26.27 dv, and the estimated 2018 URP is 22.84 dv. The modeling predicts a visibility improvement of 3.75 dv, compared to the URP improvement of 3.43 dv by 2018. Achieving the 2018 URP point is not a requirement of the RHR SIPs, but it serves as a benchmark to compare progress toward natural visibility conditions in 2064 and is designed to help states in selecting their 2018 RPGs. As stated in EPA Guidance for Setting Reasonable Progress Goals Under the Regional Haze Program[48], "The glidepath is not a presumptive target, and States may establish a RPG that provides for greater, lesser, or equivalent improvement as that described by the glidepath."

ADEQ adopted the modeled 2018 visibility conditions as the Reasonable Progress Goals for Caney Creek and Upper Buffalo Class I areas. We are proposing to disapprove Arkansas's Reasonable Progress Goals because the State did not establish the RPGs for Caney Creek and Upper Buffalo in accordance with the requirements of the RH Rule. Section 169A(g)(1) of the CAA and section 51.308(d)(1)(i)(A) of the RH Rule require states to take into account certain factors in establishing its reasonable progress goals and to demonstrate how those factors were taken into consideration in selecting the goals. ADEQ did not do so. As a result, ADEQ's RH SIP fails to ensure reasonable progress toward meeting the national visibility goal. As discussed in the following chapter, projected improvements in visibility conditions in 2018 at Caney Creek and Upper Buffalo are primarily due to reductions of sulfate emissions in other states. Sulfate emissions in Arkansas are projected to increase from 2002 to 2018. Arkansas sources are projected to remain significant contributors to visibility impairment in 2018, thus providing further support that additional analysis should have be performed according to the statutory factors. We note that there are at least two point sources in Arkansas not subject to the BART requirements that contribute to visibility impairment at Arkansas' Class I areas. This conclusion is based on the information in the RH SIP (appendix 9.2B) indicating that these sources have predicted visibility impacts exceeding the 0.5 dv threshold used by ADEQ to determine whether BART sources contribute to visibility impairment. These two sources are potential candidates for emissions controls under reasonable progress, given their contribution to visibility impairment, as may be other sources in Arkansas whose visibility impact was not evaluated by ADEQ.

The modeled visibility conditions for 2018 for the 20% best days show an improvement in visibility of 0.89 dv and 0.91dv for Caney Creek and Upper Buffalo, respectively, by 2018. This is consistent with the requirement of no degradation of visibility on the best days at Class I sites.

[48] US EPA, 2007, Guidance for Setting Reasonable Progress Goals Under the Regional Haze Program, EPA, June 2007. http://www.epa.gov/ttncaaa1/t1/memoranda/reasonable_progress_guid071307.pdf

Table 5-1. Comparison of reasonable progress goal to uniform rate of progress for 2018 (total extinction and deciviews)

	Caney Creek	Upper Buffalo
Change by 2018 (reasonable progress goal)	-3.88 dv	-3.75 dv
Change by 2018 at uniform rate of progress	-3.45 dv	-3.43 dv
Projected rate of change (2004-2018)	-0.32 dv/yr	-0.17 dv/yr
Change needed to reach natural conditions	-14.78 dv	-14.70 dv

Figure 5-1. Projections of visibility impairment for 20% worst days at Caney Creek

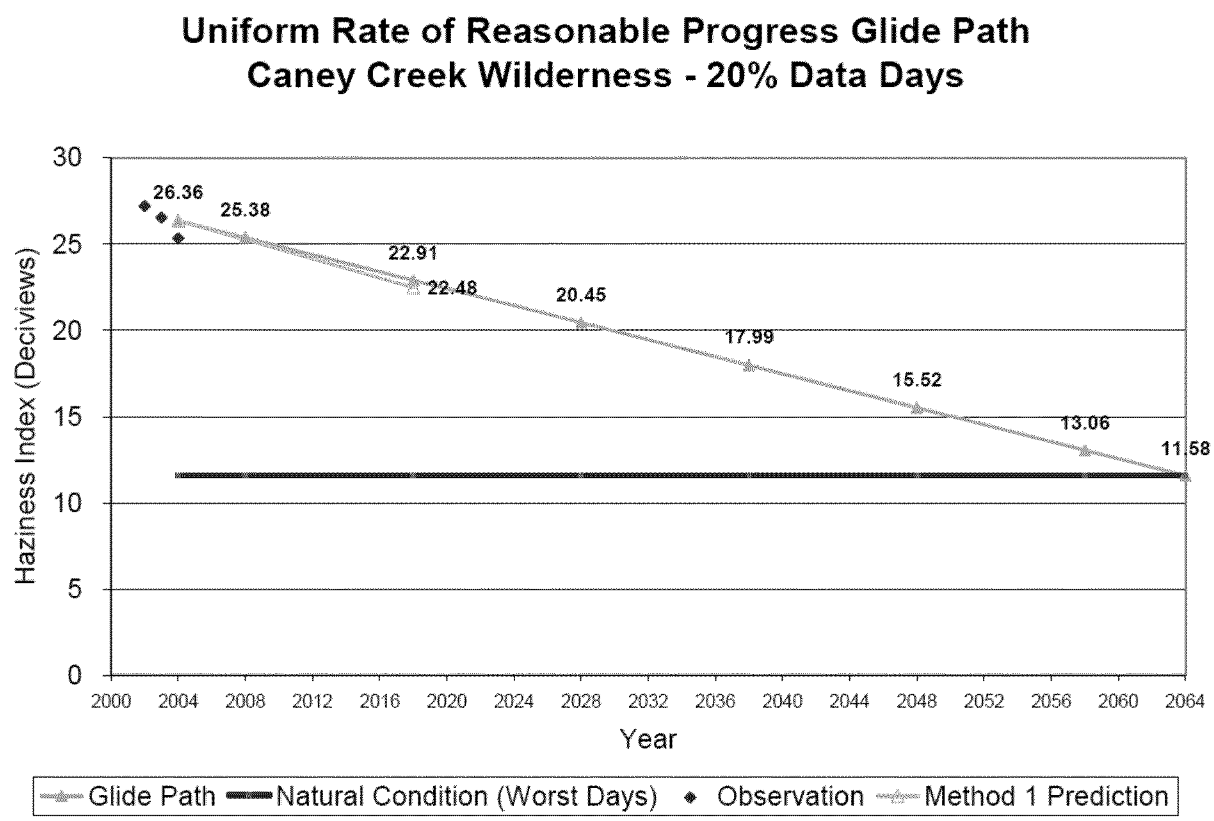
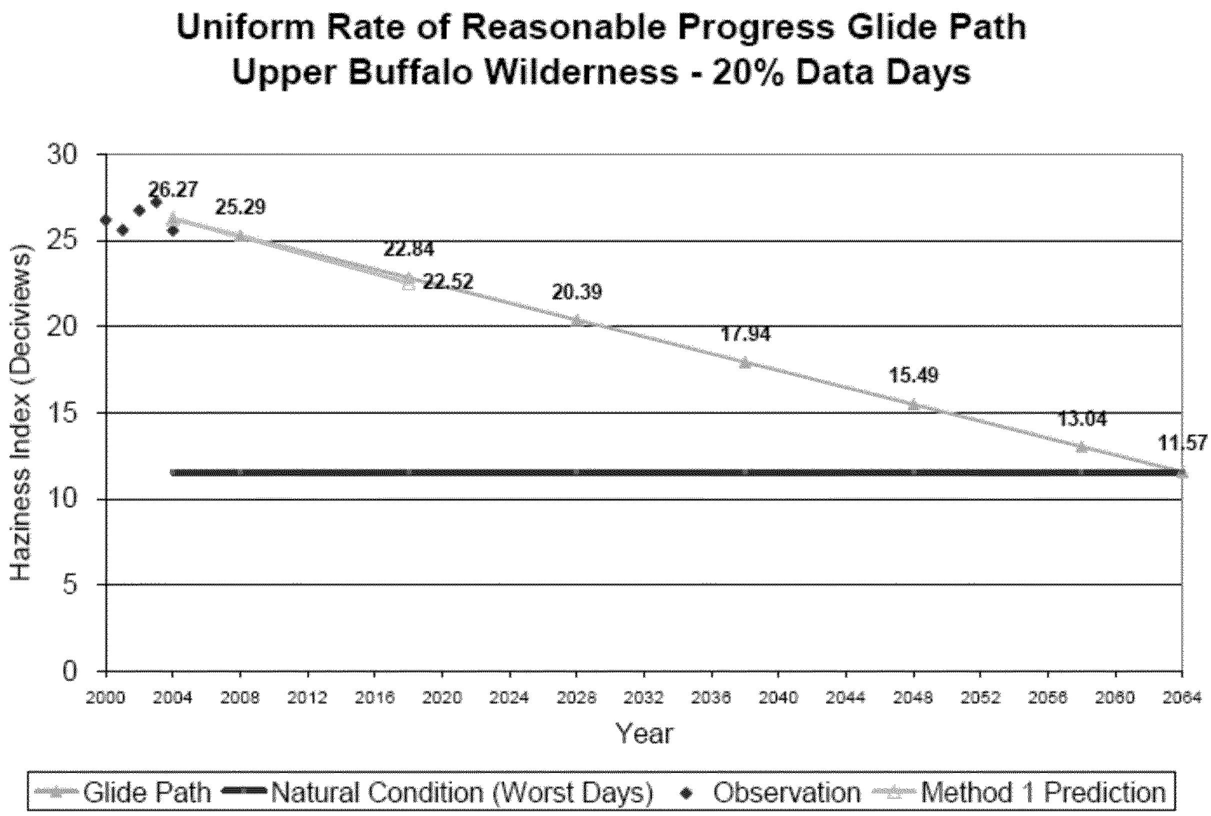


Figure 5-2. Projections of visibility impairment for 20% worst days at Upper Buffalo



Figures 5-3 and 5-4 show the differences in model results of total extinction between the Base18g and Typ02g model predictions, including the contributions from each component specie of the IMPROVE algorithm. On most days, visibility improvements are due to reductions in sulfate. A few days exhibit differences in nitrate concentrations being the most significant contribution to improved visibility.

Figure 5-3. Differences in modeled total extinction (Bext) between Base18G and Typ02g for 20% worst days at Caney Creek Wilderness Area.

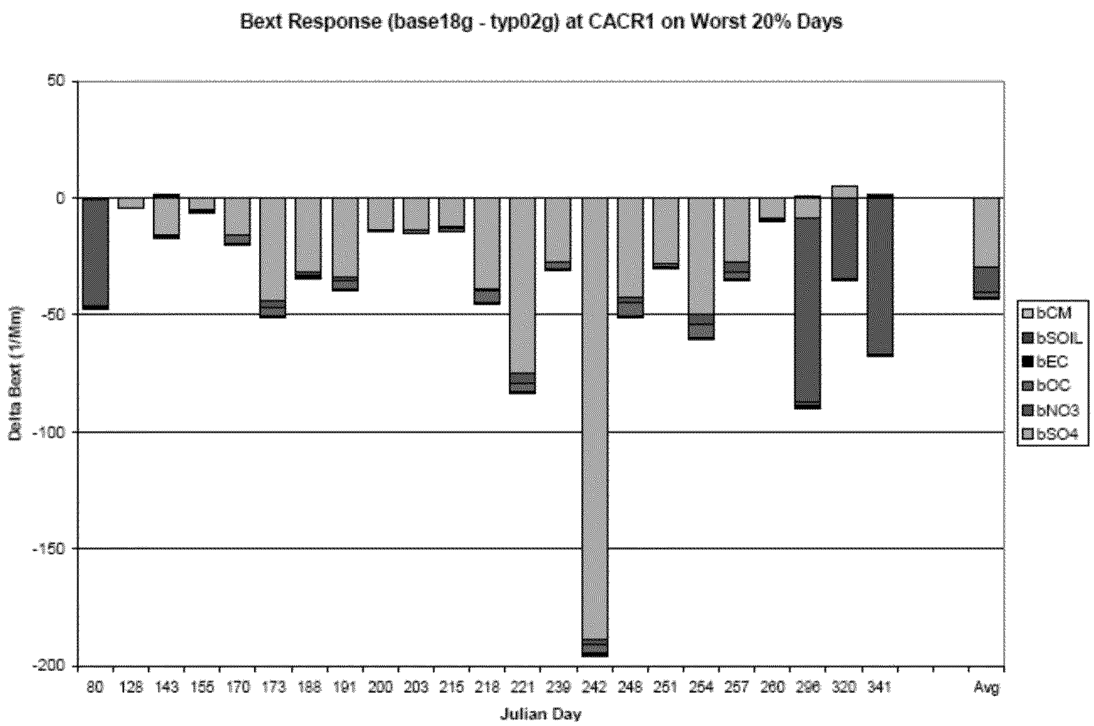
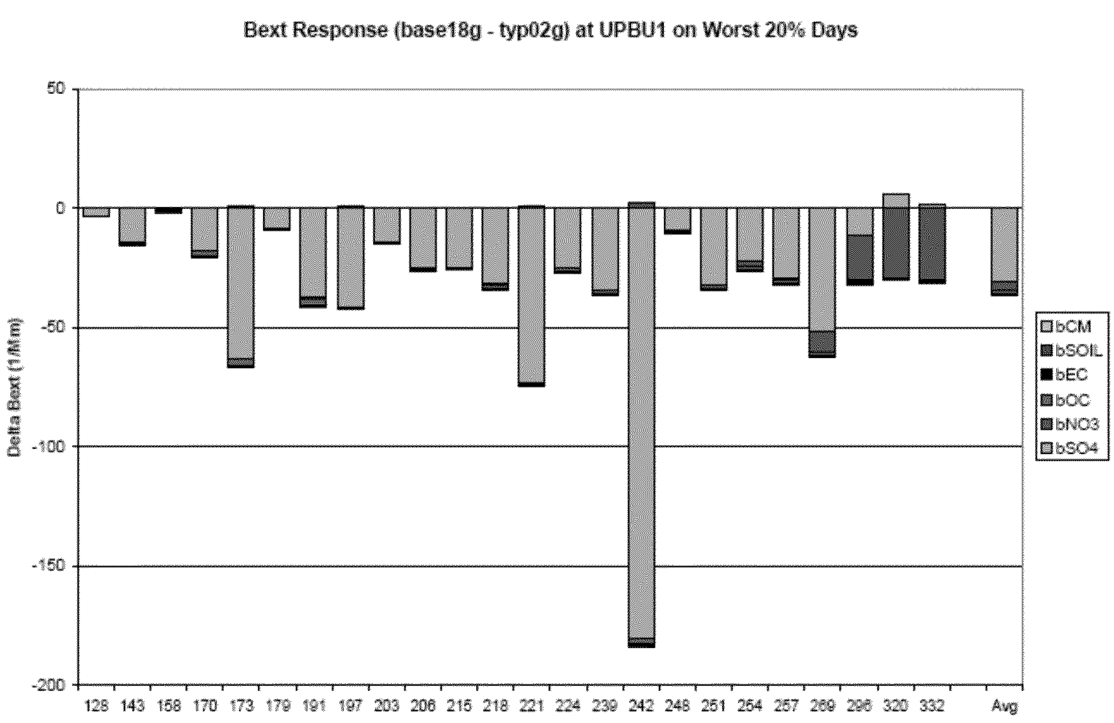


Figure 5-4. Differences in modeled total extinction (Bext) between Base18G and Typ02g for 20% worst days at Upper Buffalo Wilderness Area.



As discussed in the following chapter on source apportionment, visibility impairment at Caney Creek Wilderness Area and Upper Buffalo Wilderness Area is due to emissions and transport from outside of Arkansas as well as in state sources.

Chapter 6: Source Apportionment Modeling

6.1 INTRODUCTION

Visibility impairment in Class I areas is the result of local air pollution as well as transport of regional pollution across long distances. The relative contributions to visibility impairment from each source region and category is needed to develop effective control strategies to improve visibility. CENRAP used CAMx Version 4.40 with its Particulate Source Apportionment Technology (PSAT) tool to provide source apportionment by geographic regions and major source category. CAMx was run with similar options and inputs as the CAMQ modeling with both the 2002 baseline and 2018 future case emission inventories (Base F). The CAMX model selection and performance are discussed briefly in section 3.7 of this document and details of the CAMx model configuration used by CENRAP can be found in the CENRAP TSD and the Modeling Protocol. PSAT uses reactive tracers that operate in parallel to the CAMx host model using the same emissions, transport, chemical transformation and deposition rates as the host model to account for the contributions of user specified source regions and categories to PM concentrations throughout the modeling domain. Details on the formulation of the CAMx PSAT source apportionment can be found in the CAMx user's guidance.[49] The CAMx PSAT analysis has been tested and evaluated against other apportionment techniques.[50,51] The goals of the PSAT assessment are to evaluate the contributions of different geographic regions and source categories to visibility impairment at Class I areas in 2002 and the projected 2018 case in order to identify those regions and source categories that, if controlled, would produce the greatest improvements in visibility.

CENRAP defined 30 geographical source regions (Fig 5-1) consisting of CENRAP and nearby states, with Texas divided into 3 regions, the remainder of the western and eastern United States, the Gulf of Mexico, Canada and Mexico. Six source categories (elevated point sources; low-level point sources, on-road mobile, non-road mobile, area and natural or non-anthropogenic sources) were tracked separately. The CENRAP PSAT 2002 and 2018 applications used three of the PSAT families of tracers: 1) sulfate, 2) nitrate and ammonium, and 3) secondary organic aerosols (SOA). SOA was portioned into an anthropogenic (SOAA) and biogenic (SOAB) components. Contributions for the 20% worst and 20% best days at each CENRAP and nearby Class I area were extracted from the PSAT results. The original IMPROVE equation was used to calculate extinction coefficients from modeled concentrations. Modeling performance is poor for soil and coarse material. As discussed in Section 3 of this document, results of various projections of CM and soil had little effect on visibility predictions at the CENRAP class I areas. Extinction due to soil and coarse material changes very little between 2002 and 2018. A PSAT Visualization Tool was developed that can be used by States, Tribes and others to generate displays of the contributions of source regions and categories to visibility impairment for the

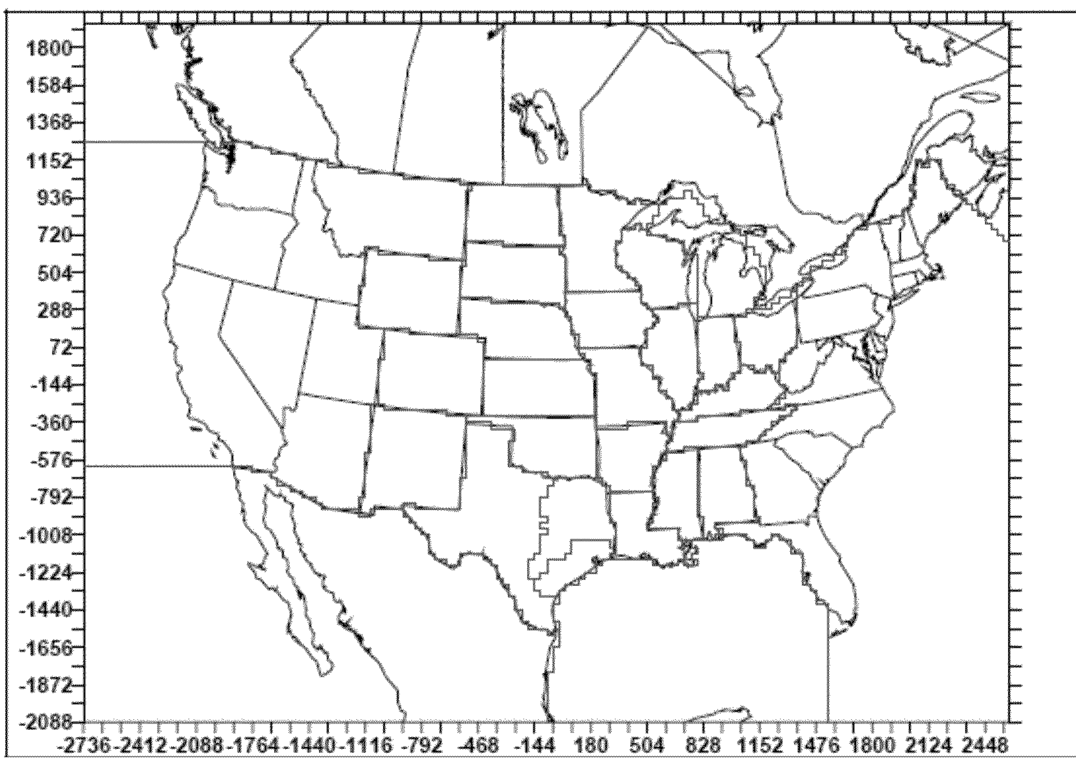
49 "User's Guide Comprehensive Air Quality Model With Extensions (CAMx) Version 4.30." ENVIRON International Corporation, Novato, California, 2006 (available at www.camx.com).

50 Morris, R.E., G.Y., C.E., G.W., B.K. 2005. "Recent Advances in One-Atmospheric Modeling Using the Comprehensive Air-quality Model with Extensions." Presented at the 98th Annual Air and Waste Management Conference, Minneapolis, MN. June.

51 Yarwood, G., R.E. Morris, G. Wilson. 2004. "Particulate Matter Source Apportionment Technology (PSAT) in the CAMx Photochemical Grid Model." Presented at the ITM 27th NATO Conference- Banff Centre, Canada, October. (http://www.camx.com/publ/pdfs/___Yarwood_ITM_paper.pdf)

average of the worst 20 percent and best 20 percent days at each CENRAP and nearby Class I areas.[52] The 2002 projected results apply the 2002 PSAT modeled source apportionment to the observed 2000-2004 Baseline extinction keeping the relative contributions of source groups to each PM species (e.g., SO4, NO3, etc.) the same averaged across the 2002 worst 20 percent days but scaling their magnitudes up or down based on the ratio of the 2000-2004 Baseline to the 2002 modeling results. Similarly, the 2018 projected results use the relative contributions of the 2018 PSAT results from each source group and scales them according to the differences in the 2018 projected PM species to the 2018 modeled PM species for the average of the worst 20 percent days. EPA believes the selection and application of CAMx for source apportionment analysis is appropriate.

Figure 6-1. Source Regions used in CAMx PSAT PM source apportionment modeling



6.2 Source Apportionment Results at Caney Creek Wilderness Area

Tables 6-1 and 6-2 show the modeled contributions to total extinction for each source category and species for 2002 and 2018, respectively. Figures 6-2, 6-3, 6-4, and 6-5 show the geographical source apportionment by source category and species for the 20% worst days in 2002 and 2018. Visibility impairment at the Caney Creek Wilderness Area site in 2002 on the worst 20% days is largely due to sulfate from point sources that contributes over half (75.1 Mm^{-1}) of the total extinction of 133.93 Mm^{-1}. The largest contributions of sulfate come from Texas (11.55 Mm^{-1} from all source categories) and the eastern United States (17.98 Mm^{-1}). Overall, the largest source region contributions to visibility impairment in 2002 are from the eastern United States (19.16 Mm^{-1}), Texas (14.89 Mm^{-1})and Arkansas (13.57 Mm^{-1}).

[52] available at http://www.cenrap.org/html/projects.php

In 2018, Arkansas sources contribute the most to visibility impairment at Caney Creek, as large reductions in impairment from point sources in East Texas and the eastern U.S. occur while sulfate emissions increase in Arkansas. The 2018 projection shows the total extinction at Caney Creek Wilderness Area for the worst 20 % days is estimated to be 85.84 Mm^{-1}, a reduction of approximately 36%. Reductions of sulfate emissions from point sources in Texas, the eastern United States, Indiana, and Ohio account for a decrease of 24.41 Mm^{-1}in total light extinction, approximately half of the total reduction between 2002 and 2018. Even with such large reductions in SO4 from point sources in 2018, extinction due to point sources is still the highest contributor to visibility impairment on the worst 20% days, accounting for over half of the total extinction. Visibility impairment from all Arkansas sources decreases 2.32 Mm^{-1}, almost entirely due to reductions from mobile sources. Total reductions in mobile sources of NO3 contribute a decrease in total extinction of approximately 9 Mm^{-1}. There is an under-prediction bias in the model that must be considered when examining source apportionment results for sulfate. Use of a 12km resolution modeling grid in CAMX reduced the summertime sulfate bias but required large computational expense. The use of higher resolution modeling should be reconsidered in future modeling efforts.

Table 6-1. Projected light extinction for 20% worst days at Caney Creek Wilderness Area in 2002 (Mm^{-1})

	Total[1]	**Point**	**Natural**	**On-Road**	**Non-Road**	**Area**
SO4	87.05	75.10	0.09	1.19	1.70	5.66
NO3	13.78	4.06	0.64	4.70	2.45	1.37
POA	10.50	1.29	1.33	0.46	1.34	5.32
EC	4.80	0.19	0.33	0.86	1.79	1.40
SOIL	1.12	0.19	0.01	0.01	0.01	0.87
CM	3.73	0.21	0.04	0.03	0.02	3.19
Sum	*133.93*	*81.04*	*2.45*	*7.26*	*7.31*	*17.81*

[1]Totals include contributions from boundary conditions and secondary organic matter

Table 6-2. Projected light extinction for 20% worst days at Caney Creek Wilderness Area in 2018 (Mm^{-1})

	Total[1]	**Point**	**Natural**	**On-Road**	**Non-Road**	**Area**
SO4	48.95	39.83	0.07	0.12	0.44	5.31
NO3	7.57	2.84	0.53	0.97	1.33	1.37
POA	9.93	1.76	1.18	0.14	1.03	5.09
EC	3.17	0.24	0.30	0.16	0.94	1.31
SOIL	1.29	0.35	0.01	0.01	0.01	0.87
CM	3.58	0.24	0.04	0.03	0.01	3.02
Sum	*85.84*	*45.27*	*2.12*	*1.44*	*3.76*	*16.96*

[1]Totals include contributions from boundary conditions and secondary organic matter

Figure 6-2. Source apportionment modeling results by source region and source category for worst 20% days at Caney Creek Wilderness Area in 2002.

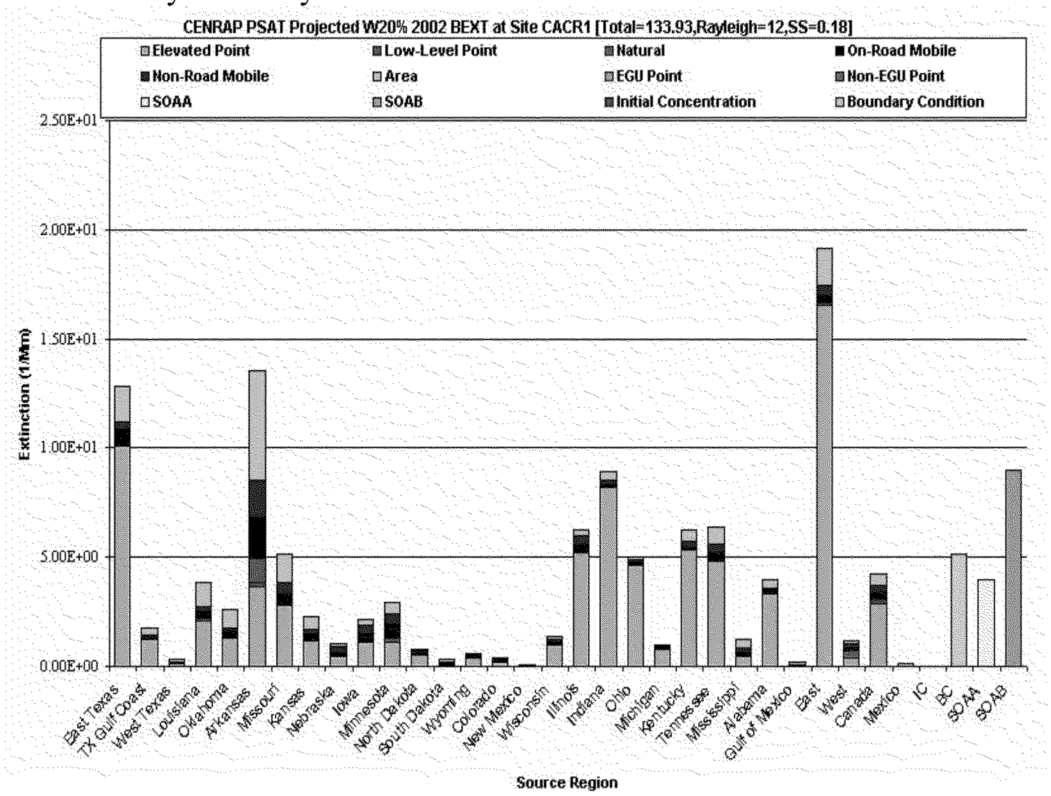


Figure 6-3. Source apportionment modeling results by source region and species for worst 20% days at Caney Creek Wilderness Area in 2002.

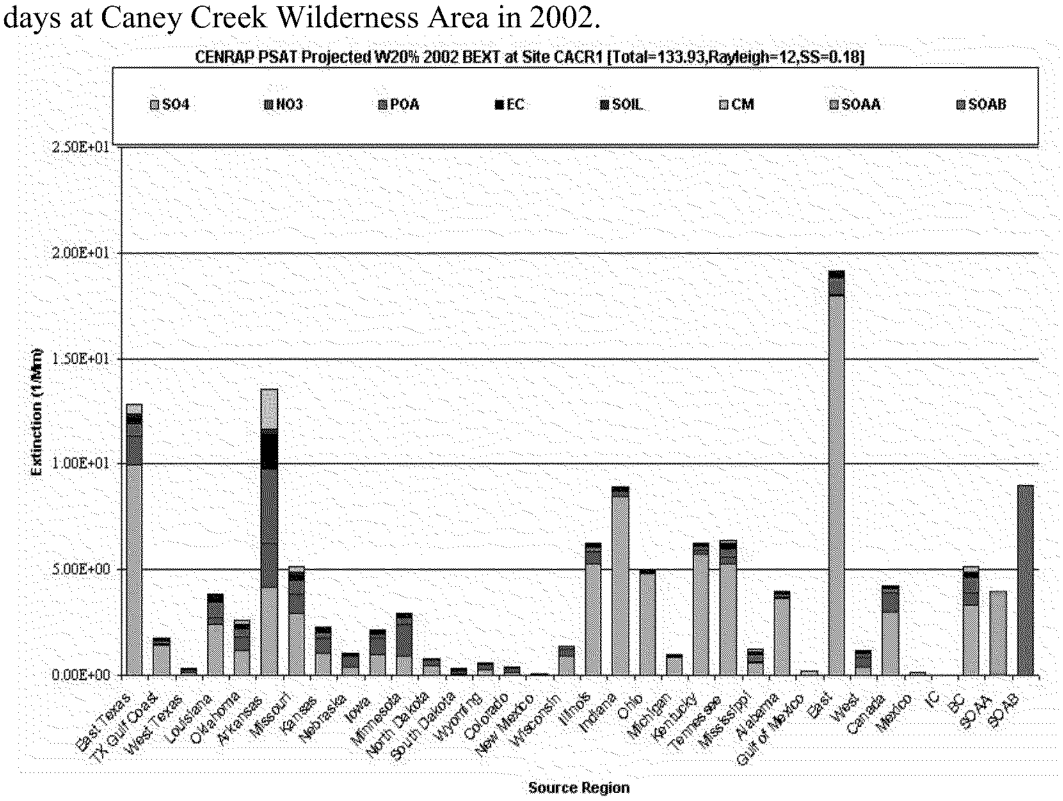
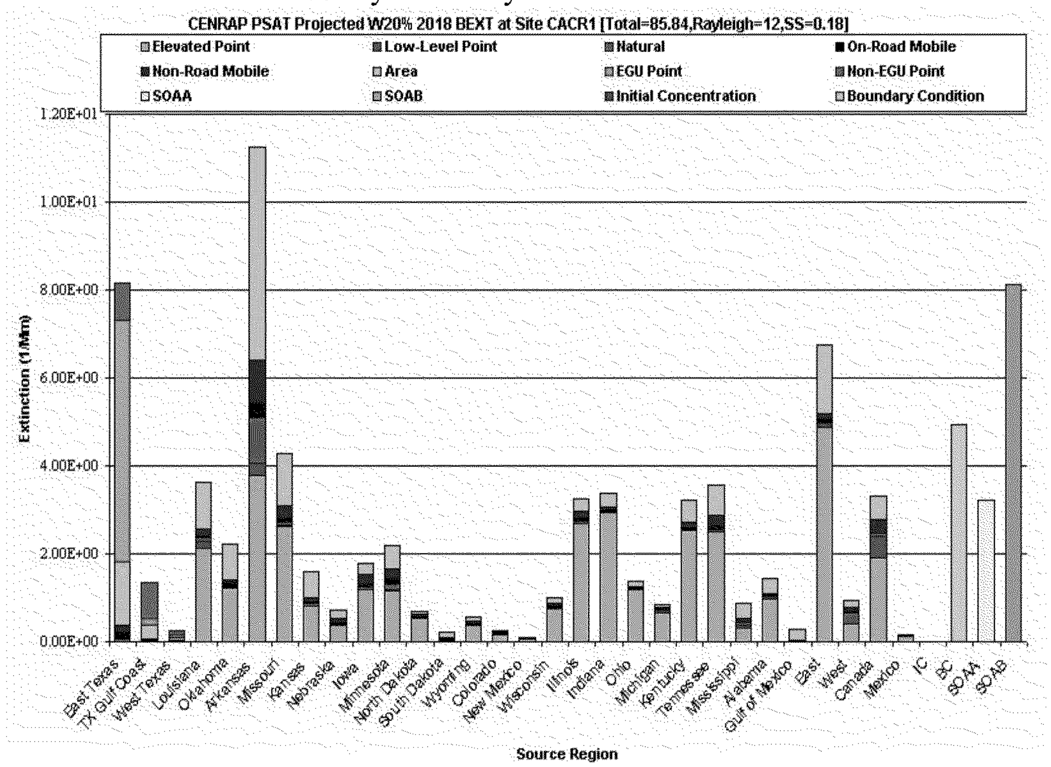
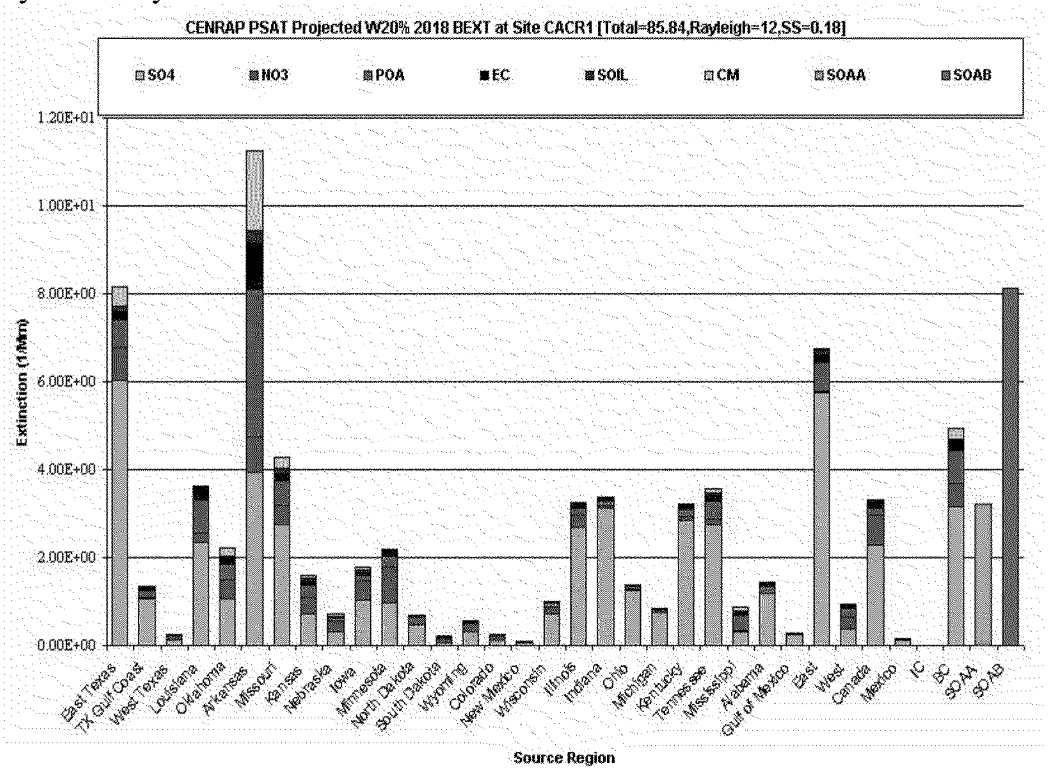


Figure 6-4. Source apportionment modeling results by source region and source category for worst 20% days at Caney Creek Wilderness Area in 2018.



*2018 projections for Texas Point sources are divided into EGU and Non-EGU point sources

Figure 6-5. Source apportionment modeling results by source region and species for worst 20% days at Caney Creek Wilderness Area in 2018.



6.3 SOURCE APPORTIONMENT RESULTS AT UPPER BUFFALO WILDERNESS AREA

Tables 6-3 and 6-4 show the contributions to total extinction for each source category and species for 2002 and 2018, respectively. Figures 6-6, 6-7, 6-8, and 6-9 show the geographical source apportionment by source category and species for the 20% worst days in 2002 and 2018. Visibility impairment at the Upper Buffalo Wilderness Area site in 2002 on the worst 20% days is largely due to sulfate from point sources that contributes over half (72.17 Mm^{-1}) of the total extinction of 131.79 Mm^{-1}. The largest contributions of sulfate come from the eastern United States (18.56 Mm^{-1}), Indiana (9.79 Mm^{-1}), Illinois (8.06 Mm^{-1}), and Kentucky (6.93 Mm^{-1}). Overall, the largest source region contributions to visibility impairment in 2002 are from the eastern United States (20.00 Mm^{-1}), Arkansas (13.47 Mm^{-1}), Indiana (10.20 Mm^{-1}), Illinois (9.64 Mm^{-1}), and Missouri (9.60 Mm^{-1}).

In 2018, Arkansas sources contribute the most to visibility impairment at Upper Buffalo, as large reductions in impairment from point sources in Indiana, Illinois, Ohio and the eastern U.S. occur while sulfate emissions increase in Arkansas. The 2018 projection shows the total extinction at Upper Buffalo Wilderness Area for the worst 20 % days is estimated to be 86.16 Mm^{-1}, a reduction of approximately 35%. Reductions of sulfate emissions from point sources in the eastern United States, Indiana, Illinois, Kentucky and Ohio account for a decrease of 28.43 Mm^{-1} in total light extinction, more than 60% of the total reduction in impairment between 2002 and 2018. Even with such large reductions in SO4 from point sources in 2018, extinction due to point sources is still the highest contributor to visibility impairment on the worst 20% days, accounting for approximately half of the total extinction. Visibility impairment from all Arkansas sources decreases 1.45 Mm^{-1}, due to reductions from mobile sources. Total reductions in mobile sources of NO3 contribute a decrease in total extinction of approximately 8.5 Mm^{-1}. There is an under-prediction bias in the model that must be considered when examining source apportionment results for sulfate. Use of a 12km resolution modeling grid in CAMX reduced the summertime sulfate bias but required large computational expense. The use of higher resolution modeling should be reconsidered in future modeling efforts.

Table 6-3. Projected light extinction for 20% worst days at Upper Buffalo Wilderness Area in 2002 (Mm^{-1})

	Total[1]	Point	Natural	On-Road	Non-Road	Area
SO4	83.18	72.17	0.08	1.15	1.67	5.24
NO3	13.30	3.93	0.61	4.14	2.71	1.23
POA	10.85	1.06	1.33	0.47	1.38	5.75
EC	4.72	0.16	0.31	0.80	1.93	1.30
SOIL	1.21	0.20	0.02	0.01	0.01	0.93
CM	6.85	0.29	0.05	0.05	0.02	6.02
Sum	*131.79*	*77.80*	*2.39*	*6.62*	*7.72*	*20.46*

[1]Totals include contributions from boundary conditions and secondary organic matter

Table 6-4. Projected light extinction for 20% worst days at Upper Buffalo Wilderness Area in 2018 (Mm^{-1})

	Total[1]	Point	Natural	On-Road	Non-Road	Area
SO4	45.38	37.09	0.06	0.12	0.42	4.95
NO3	9.22	3.48	0.63	1.10	1.81	1.48
POA	10.17	1.48	1.20	0.14	1.01	5.49
EC	3.07	0.21	0.28	0.15	0.99	1.21
SOIL	1.40	0.40	0.01	0.01	0.01	0.93
CM	6.53	0.36	0.05	0.04	0.02	5.65
Sum	*86.16*	*43.02*	*2.24*	*1.57*	*4.25*	*19.71*

[1]Totals include contributions from boundary conditions and secondary organic matter

Figure 6-6. Source apportionment modeling results by source region and source category for worst 20% days at Upper Buffalo Wilderness Area in 2002.

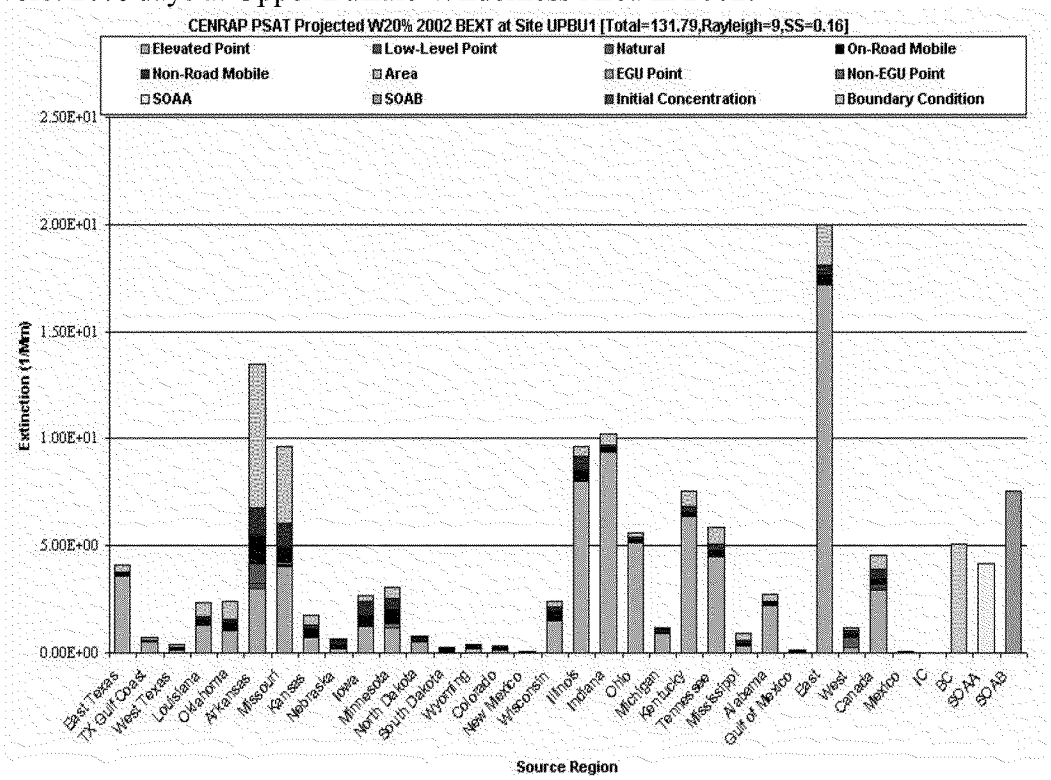


Figure 6-7. Source apportionment modeling results by source region and species for worst 20% days at Upper Buffalo Wilderness Area in 2002.

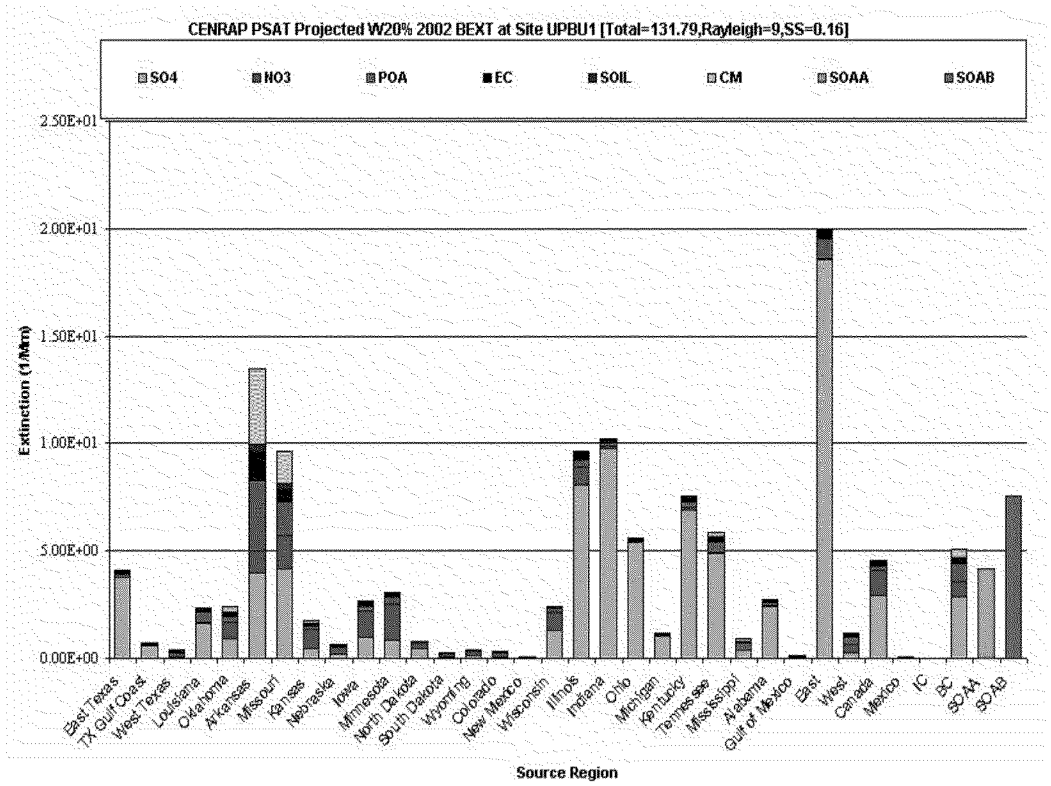
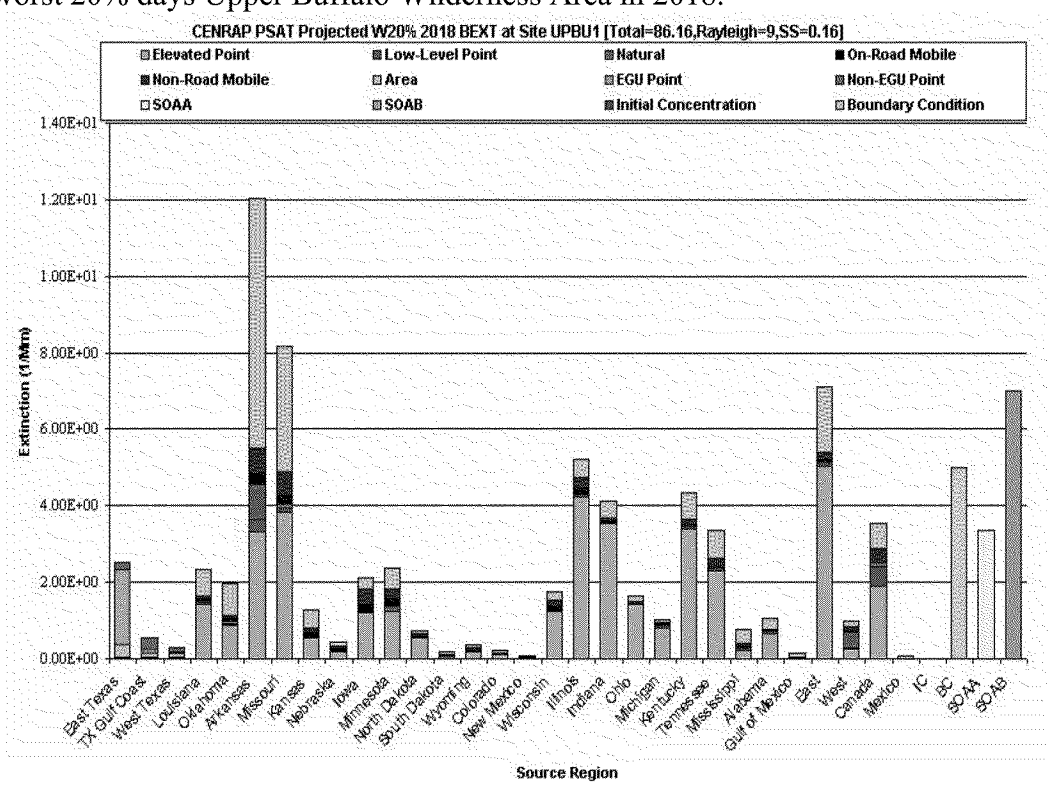
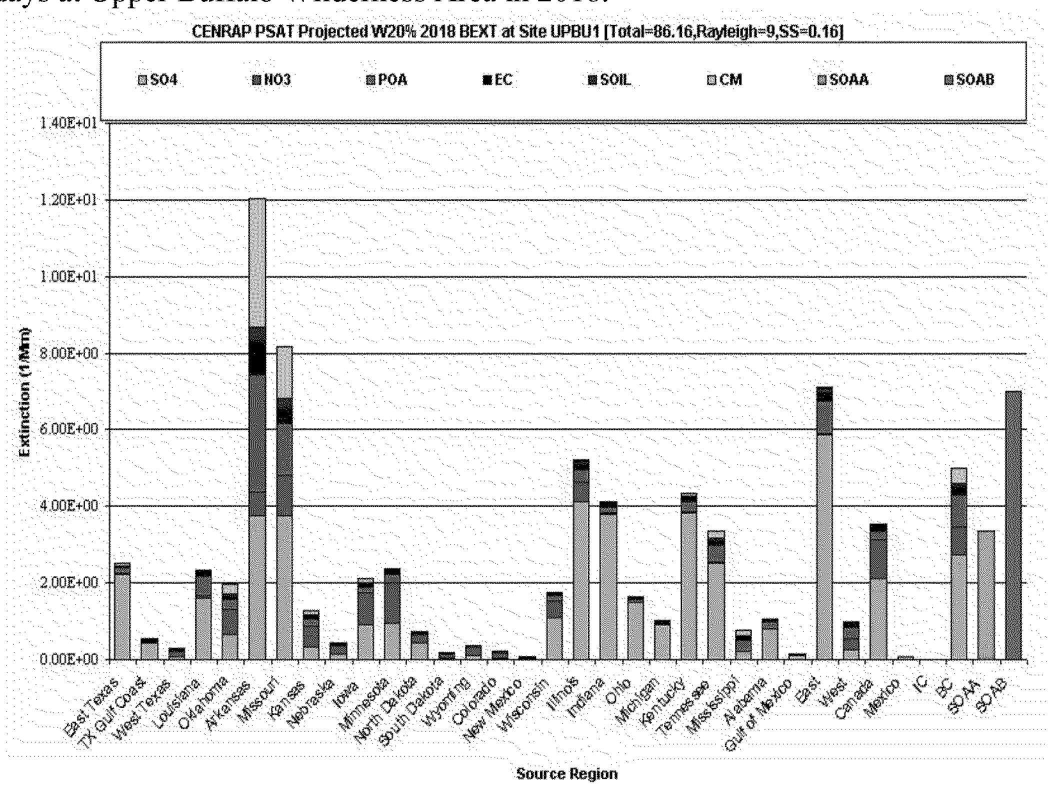


Figure 6-8. Source apportionment modeling results by source region and source category for worst 20% days Upper Buffalo Wilderness Area in 2018.



*2018 projections for Texas Point sources are divided into EGU and Non-EGU point sources

Figure 6-9. Source apportionment modeling results by source region and species for worst 20% days at Upper Buffalo Wilderness Area in 2018.



6.4 CONTRIBUTIONS TO VISIBILITY IMPAIRMENT AT OTHER CLASS I AREAS

CAMx PSAT results are also utilized to evaluate the impact of Arkansas emission sources in 2002 and 2018 on visibility impairment at Class I areas outside of the state. Arkansas sources are modeled to have contributions to the Class I areas in Missouri (Hercules-Glades and Mingo). Outside of Arkansas and Missouri, the largest contribution from Arkansas sources is at the Wichita Mountains Class I area in Oklahoma that amounts to 2.0 % of visibility impairment in 2002 and 2.3% in 2018. We note that any additional reductions that may occur due to ADEQ refinements in BART determinations would likely be beneficial in reducing Arkansas sources impacts on Class I areas with Arkansas and outside of Arkansas.

Table 6-5. Percent contribution to total visibility impairment at Class I areas on 20% worst days from Arkansas Sources (contributions less than 1% are excluded)

Class I area	2002	2018
UPBU1	10.2%	14.0%
CACR1	10.1%	13.1%
HEGL1	5.9%	7.6%
MING1	3.3%	4.4%
WIMO1	2.0%	2.3%
MACA1	1.0%	1.8%
BOND1	1.2%	1.5%
BRET1	1.1%	1.3%
CADI1	0.9%	1.2%

Chapter 7: BART Determination

7.1 INTRODUCTION

The Clean Air Act establishes the national goal of eliminating man-made visibility impairment from all Class 1 areas. As a part of the plan for achieving this goal Section 169A(b)(2)(A) of the act requires certain major stationary sources in existence between 1962 and 1977 to be reviewed for Best Available Retrofit Technology (BART). Arkansas DEQ identified facilities in the affected source categories with potential emissions over the BART rule threshold of 250 tons per year for any visibility-impairing pollutant (NOx, SO_2, and PM) from any unit that was in existence on August 7, 1977 and began operation after August 7, 1962. Table 7-1 shows all facilities within Arkansas that have units that were determined to be BART-eligible by ADEQ.

Table 7-1. Facilities with BART-eligible units in Arkansas

BART source category	Facility name	County	Number of units
Fossil fuel-fired boilers of more than 250 MMBTU/hr heat input	AEP Flint Creek Power Plant	Benton	1
	Arkansas Electric Cooperative Corporation Carl E. Bailey Generating Station	Woodruff	1
	Arkansas Electric Cooperative Corporation John L. McClellan Generating Station	Ouachita	1
	Entergy Lake Catherine Plant	Hot Spring	1
	Entergy Robert E. Ritchie Plant	Phillips	1
	Entergy White Bluff Plant	Jefferson	3
Kraft pulp mills	Domtar Ashdown Mill	Little River	2
	Delta Natural Kraft	Jefferson	1
	Evergreen Packaging/International Paper	Jefferson	1
	Georgia Pacific Crossett Mill	Ashley	1
	Green Bay Packaging	Conway	1
	Potlach Forest Products/Clearwater Paper Corporation Cypress Bend Mill	Desha	1
Petroleum refineries	Lion Oil Company	Union	1
Sulfur recovery plant	Albermarle Corporation South Plant	Columbia	1
Sintering plants	Big River Industries- Arkalite	Crittenden	1
Chemical processing plants	Albermarle Corporation South Plant	Columbia	2
	Future Fuels/Eastman Chemical Company	Independence	3
	El Dorado Chemical Company	Union	3

We note that in Chapter 15 of APC&E Regulation 19, contained in the submittal we received on September 23, 2008, and as revised by the submittal we received on August 3, 2010, ADEQ identified one more unit (not listed in Table 7-1), the 6A Boiler at Georgia-Pacific Crossett Mill, as being BART eligible. ADEQ did not identify the 6A Boiler as BART eligible in the RH SIP narrative. Appendix 9.1A states the 6A Boiler began operation prior to August 7, 1962, and therefore falls out of the eligibility criteria. On September 27, 2011, ADEQ submitted supplemental information clarifying that the Georgia-Pacific Crossett Mill provided ADEQ a copy of a boiler inspection report for the 6A Boiler, which states that the inspection of the new boiler took place on August 6, 1962, to determine if the boiler complied with the State and

American Society of Mechanical Engineers (ASME) codes.[53] However, ADEQ stated it cannot say with certainty whether the 6A boiler was in operation as of August 6, 1962, or at a later date.[54] Since there is not sufficient information to determine the date of start of operations of the 6A Boiler, we cannot make the determination that the boiler is not BART eligible. Therefore, we are proposing to find that the 6A Boiler at the Georgia-Pacific Crossett Mill is BART eligible

In the RH SIP, ADEQ identified one unit (the No. 4 recovery boiler) at International Paper/ Evergreen Packaging as BART eligible (shown in Table 7-1 ADEQ included two other units (the No. 1 and 2 Power Boilers) at International Paper/Evergreen Packaging in its evaluation to determine what sources are subject to BART The International Paper/Evergreen Packaging No. 1 and No. 2 Power Boilers are not BART-eligible because they were constructed and were in operation prior to August 7, 1962.[55] We agree that the No. 1 and 2 Power Boilers at International Paper/Evergreen Packaging are not BART-eligible.

In the RH SIP, ADEQ did not identify Boilers SN-301A and SN-302A at the Great Lakes Chemical Plant as BART-eligible, but since these units were at one point believed to be BART eligible, ADEQ included these units in its evaluation to determine what sources are subject to BART. EPA reviewed the federally enforceable operating permit for the Boilers SN-301A and SN-302A at the Great Lakes Chemical Plant and determined that Boilers SN-301A and SN-302A are not BART eligible because they are boilers with a heat input rating less than 250 MMBtu/hr and are not integral to the process, as the permit states they supply heat to the process. The BART Guidelines provide that an individual fossil fuel boiler smaller than 250 MMBtu/hr that does not fall into source Category 1 (i.e., Fossil-fuel fired steam electric plants of more than 250 MMBtu/hr heat input), falls into one of the source categories for BART eligibility only if it is an integral part of a process description at a plant. If the boiler is integral to the process description at a plant, it falls into the source category of the process which it serves. In general, if the boiler serves the process in any way beyond contributing heat, it is integral to the process. Based on information in the current operating air permit for the Great Lakes Chemical Plant, we agree that Boilers SN-301A and SN-302A are not BART-eligible.[56]

As discussed above, there is a discrepancy between the BART eligible sources identified in the RH SIP narrative, and those identified in the State's RH Rule. Because ADEQ submitted supplemental information on September 27, 2011, clarifying that it did not know with certainty the startup date of operations of the 6A Boiler at the Georgia-Pacific Crossett Mill, we are proposing to find that the 6A Boiler is BART eligible. We are proposing to approve ADEQ's identification of the remaining BART-eligible sources.

Pursuant to federal regulations, states have the option of exempting a BART-eligible source from the BART requirements based on dispersion modeling demonstrating that the source cannot reasonably be anticipated to cause or contribute to visibility impairment in a Class I area.

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[53] A copy of the boiler inspection report for the 6A Boiler at the Georgia-Pacific Crossett Mill can be found in the docket for this proposed rulemaking.

[54] The BART Guidelines define "in operation" as "engaged in activity related to the primary design function of the source."

[55] Letter from ADEQ (William Swafford) to International Paper Company (Kelly Bryant), RE: BART eligibility of Power Boilers 1 and 2, SN-13 and SN-15, August 30, 2006

[56] The current air permit for the Great Lakes Chemical Plant can be found in the docket for this rulemaking.

According to 40 CFR Part 51, Appendix Y[57] , a BART eligible source is considered to "contribute" to visibility impairment in a Class I area if the modeled 98th percentile change in deciviews is equal to or greater than the "contribution threshold." The original meteorological databases generated by CENRAP did not include observations as EPA guidance recommends. Therefore, in their evaluation of sources for BART purposes, states used the 1st high values (i.e., maximum value) of modeled visibility impacts instead of the 8th high values (98^{th} percentile value). The use of the 1st high modeled values was agreed to by EPA, representatives of the Federal Land Managers, and CENRAP stakeholders. Any BART-eligible source determined to cause or contribute to visibility impairment in any Class I area is subject to BART. The EPA BART Guidelines state that the contribution threshold used to determine whether a source "contributes" to visibility impairment should not be higher than 0.5 deciview. States have the option to establish alternative, lower thresholds. ADEQ applied the 0.5 deciview threshold to the BART-eligible sources. To determine whether a source exceeds the BART contribution threshold, EPA recommends use of the CALMET/CALPUFF modeling system; the main components of this modeling system are CALMET (a diagnostic three-dimensional meteorological model), CALPUFF (an air quality dispersion model), and CALPOST (a post-processing package). CENRAP developed a BART modeling protocol in 2005 with input from EPA Region 6, 7 and representatives of the Federal Land Managers. Table 7-2 shows those facilities that were granted waivers from BART based on dispersion modeling results.

Table 7-2. Facilities granted waivers from BART based on ADEQ screening modeling.

Facility name	Maximum impacted Class I area	Maximum visibility impact
Delta Natural Kraft	HEGL	0.02
Big River Industries- Arkalite	MING	0.09
Entergy Robert E. Ritchie Plant	SIPS	0.10
Clearwater Paper Corporation Cypress Bend Mill	CACR	0.12
Green Bay Packaging	CACR	0.17
Lion Oil Company	HEGL	0.19
Albermarle Corporation South Plant	CACR	0.30
El Dorado Chemical Company	CACR	0.31
Future Fuels Chemical Company	HEGL	0.71

In Appendix 9.2B of the RH SIP, ADEQ provided screening modeling results for all sources identified in the RH SIP as BART-eligible sources, as well as for Boilers SN-301A and SN-302A at Great Lakes Chemical and the No. 1 and No. 2 Power Boilers at International Paper/Evergreen Packaging, and the 6A and 9A Boilers at the Georgia-Pacific Crossett Mill (as discussed above). Our evaluation of these results showed that four BART eligible facilities that were not identified as subject-to-BART by ADEQ had modeled visibility impacts that exceed the chosen threshold of 0.5 dv.

- ADEQ included the No. 1 and No. 2 Power Boilers at International Paper/Evergreen Packaging and Boilers SN-301A and SN-302A at Great Lakes Chemical in its modeling evaluation to determine what sources are subject to BART. As discussed above, we are proposing to approve ADEQ's identification of these two sources as not BART-eligible and not subject to BART.
- The original meteorological databases generated by CENRAP did not include observations as EPA guidance recommends. Therefore, in their evaluation of sources for BART purposes, states used the 1st high values (i.e., maximum value) of modeled visibility impacts instead of the 8th high values (98^{th} percentile value). The use of the 1st high modeled values was agreed to by EPA, representatives of the Federal Land Managers, and CENRAP stakeholders. ADEQ's modeling shows that Future Fuels/ Eastman Chemical has a modeled visibility impact of 0.711 dv at Hercules-Glade. Further examination of the modeling results reveal that only one day of the three years modeled exceeds the threshold value at any Class I area. Since only one day is projected above the threshold, we believe it is very unlikely that a refined modeling approach, using updated meteorological data which would allow for the use of the 98^{th} percentile modeled visibility impact rather than the maximum impact, would show modeled impacts above the threshold. Therefore, we are proposing that this facility is not subject-to-BART.
- The visibility modeling provided in Appendix 9.2B of the Arkansas RH SIP shows that the 9A Boiler of the Georgia-Pacific Crossett Mill has visibility impacts exceeding the 0.5 dv contribution threshold, with a visibility impact above 1 dv at Caney Creek and Hercules-Glade. EPA also reviewed ADEQ's revised modeling for this source, which looked at the visibility impacts of both the 6A and 9A Boilers at the Georgia-Pacific Crossett Mill. Using updated emission rates, the revised modeling showed projected visibility impacts of the two boilers combines below the 0.5 dv threshold. For SO_2, the modeled emission rate for the 9A Boiler was revised from the permit limit of 613.3 lbs/hr to 306.7 lbs/hr, based on the assumption that the scrubber in use will reduce emissions by 50%.[58] Georgia-Pacific also states that stack test data was used to give a more accurate emission factor for SO_2 emissions and that this factor was used with worst-case actual monthly fuel usage to determine an emission rate.[59] For NOx, the facility proposed good combustion practices and reduced the modeled emissions of the 9A Boiler to 244.4 lbs/hr.[60] We note that the current permit limits for the 9A Boiler for SO_2 is 502.5 lb/hr

[58] Letter from Georgia-Pacific (James Cutbirth) to ADEQ (Michael Watt), RE: Proposed Best Available Retrofit Technology (BART) Emission Reductions from Georgia-Pacific Corporation Crossett Mill 9A Boiler, November 3, 2006

[59] Two letters from Georgia-Pacific (James Cutbirth) to ADEQ (Mike Bates), RE: Georgia-Pacific LLC Crossett Paper BART Emissions AFIN: 02-00013 Permit Number: 597-AOP-R8, Janurary 26, 2007; Letter from Georgia-Pacific (Karen Dickinson) to ADEQ (Mary Pettyjohn) , RE: Georgia-Pacific Corporation Crossett BART Emissions AFIN: 02-00013 Permit Number: 597-AOP-R8, December 11, 2006

[60] Letter from Georgia-Pacific (James Cutbirth) to ADEQ (Michael Watt), November 3, 2006; ; RE: Proposed Best Available Retrofit Technology (BART) Emission Reductions from Georgia-Pacific Corporation Crossett Mill 9A Boiler

and 218 lb/hr for NOx.[61] From the data provided, it is unclear if the modeled emissions are representative of the actual maximum 24 hour emissions from the highest emitting day over the modeled period. There is no supporting technical analysis explaining how the stack test data were used to estimate maximum emissions nor is fuel usage information provided for the modeled period. We are proposing to disapprove ADEQ's determination that Georgia Pacific Crossett Mill's 6A and 9A boilers are not subject-to-BART because ADEQ has not modeled the visibility impact of the 6A and 9A Boilers using acceptable estimates of maximum 24 hour emissions, and as a result we do not know if the boilers have a combined visibility impact below the 0.5 dv contribution threshold or not. Based on the original modeled visibility impact resulting when permit allowables for SO_2 are modeled (Appendix 9.2B of the RH SIP), the two boilers are subject-to-BART. and require a full BART analysis.

We are proposing to approve ADEQ's identification of subject-to-BART sources, except for ADEQ's determination that the Georgia-Pacific Crossett Mill 6A and 9A Boilers are not subject to BART.

7.2 BART DISPERSION MODELING PROTOCOL

7.2.1 Overview of Modeling Approach

In the CENRAP region, the states themselves took the lead in the BART modeling, but CENRAP provided modeling guidance[62] and readily available modeling data bases that were used by states and/or source operators in many cases to conduct their analyses. In development of these guidelines, CENRAP followed the EPA BART guidelines[63] and the applicable CALMET/CALPUFF modeling guidance [64] in effect at the time the analysis was conducted. ADEQ performed source-specific dispersion modeling using CALPUFF to determine if the source causes or contributes to visibility impairment in any Class I area.

Using the procedures in the modeling guidelines, ADEQ conducted initial subject-to-BART screening to determine whether or not the source contributes significantly (above the 0.5 dv

[61] ADEQ Operating Air Permit, Permit No. : 0597-AOP-RI3, issued to: Georgia-Pacific LLC - Crossett Paper Operations, August 4, 2011

[62] CENRAP BART Modeling Guidelines, Tesche, T. W., Dennis E. McNally, and George J. Schewe, Alpine Geophysics, LLC, 2005.

[63] EPA. 2005. "Regional Haze Regulations and Guidelines for Best Available Technology (BART) Determinations". Fed. Reg./Vol. 70, No. 128/Wed. July 6, 2005, Rules and Regulations, pp. 39104-39172. 40 CFR Part 51, FRL-7925-9, RIN AJ31.

[64] Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long-Range Transport and Impacts on Regional Visibility, EPA- 454/R-98-019, IWAQM, 1998; "Federal Land Managers' Air Quality Related Values Workgroup (FLAG)": Phase I Report, FLAG, USDI – National Park Service, Air Resources Division, Denver, CO., 2000. http://www.nature.nps.gov/air/Pubs/pdf/flag/FlagFinal.pdf;. EPA, 2003. "Revisions to the Guideline on Air Quality Models: Adoption of a Preferred Long Range Transport Model and Other Resources"; Final Rule. Fed. Reg./Vol. 68, No. 72/Tuesday April 15, 2003/Rules and Regulations. 40 CFR51.

threshold) to visibility impairment at any Class I area. Visibility impairment is calculated in relation to the natural background visibility conditions described in the GENV. ADEQ's BART Modeling Protocol (Appendix 9.2A of the AR RH SIP) is consistent with the CENRAP BART screening modeling protocol. We note that the original meteorological databases generated by CENRAP and used by ADEQ did not include observations as EPA guidance recommends, therefore sources were evaluated using the 1st High values instead of the 8th High values. The use of the 1st High modeling values was agreed to by EPA, representatives of the Federal Land Managers, and CENRAP stakeholders. Sources modeled below 0.5 deciviews impact at any Class I area were determined to be exempt from BART. Each facility was modeled individually; evaluating the visibility impacts at the five Class I areas within 300km of any BART-eligible source in Arkansas (Figure 7-1). Appendix 9.2B of the AR RH SIP includes the modeling files for the BART-eligible sources. ADEQ used those results, in conjunction with other information, to determine whether or not the individual BART-eligible source will be subject to BART control requirements. ADEQ notified those facilities that were determined to be subject-to-BART (Table 7-3) and provided guidance on how to conduct the BART analyses.

ADEQ also performed post-control CALPUFF modeling to determine the amount of visibility improvement anticipated from the controls determined to be BART by the facilities and ADEQ (Appendix 9.3C of the AR RH SIP). ADEQ's summary of each of these facilities' BART determinations can be found in Chapter 9 of the AR RH SIP. The BART analysis conducted by the facility for each subject-to-BART source is included in Appendix 9.3A of the AR RH SIP.

Figure 7-1. Map showing Arkansas's BART-eligible sources and the 300 km radius buffer zones around five separate receptors (north, south, east, west, and center) located in the following Class I areas: Upper Buffalo (UPBU), Caney Creek (CACR), Hercules Glade (HEGL), Mingo (MING), and Sipsey (SIPS)

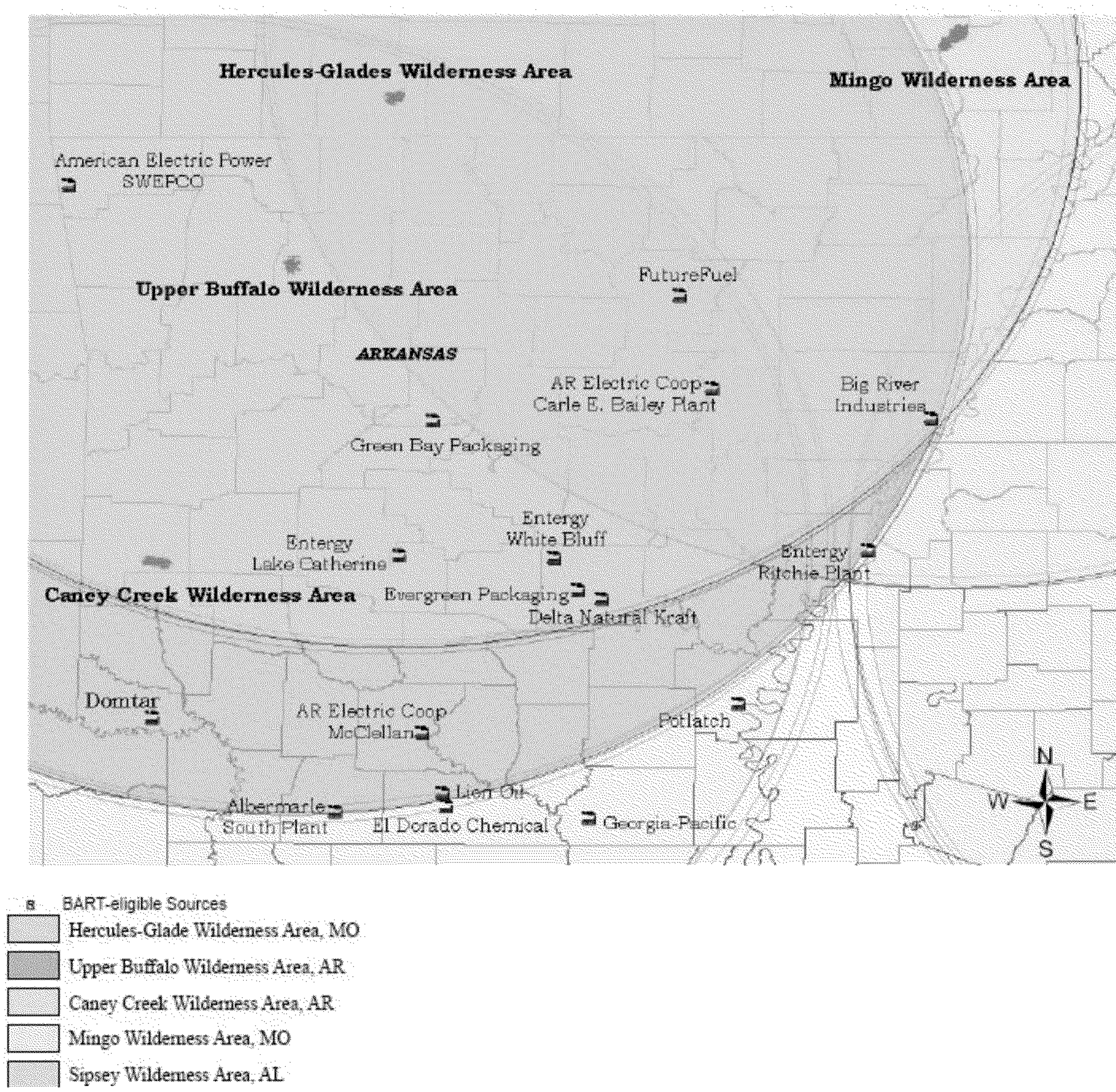


Table 7-3. Sources in Arkansas determined to be subject to BART by ADEQ

Facility Name	BART Emission Units	Source Category	Pollutants Evaluated
Arkansas Electric Cooperative Corporation Carl E. Bailey Generating Station	Unit 1	fossil fuel-fired steam electric plants	SO_2
			NOx
			PM_{10}
Arkansas Electric Cooperative Corporation John L. McClellan Generating Station	Unit 1	fossil fuel-fired steam electric plants	SO_2
			NOx
			PM_{10}
American Electric Power Flint Creek Power Plant	Boiler No. 1	fossil fuel-fired steam electric plants	SO_2
			NOx
			PM_{10}
Entergy Lake Catherine Plant	Unit 4	fossil fuel-fired steam electric plants	SO_2
			NOx
			PM_{10}
Entergy White Bluff Plant	Units 1, 2, and Auxiliary Boiler	fossil fuel-fired steam electric plants	SO_2
			NOx
			PM_{10}
Domtar Ashdown Mill	Boilers No. 1 and 2	kraft pulp mill	SO_2
			NOx
			PM_{10}

7.2.2 Model Selection and Applicability

Relevant guidance[65] states that the CALPUFF model is generally applicable at distances from 50 km to at least 200-300 km downwind of a source. BART screening analyses were performed with the 5.53a/5.753 versions of CALMET/CALPUFF, which were acceptable versions at the time the modeling was performed. Visibility impacts were modeled at Caney Creek Wilderness Area (CACR), Upper Buffalo Wilderness Area (UPBU), Mingo National Wildlife Refuge

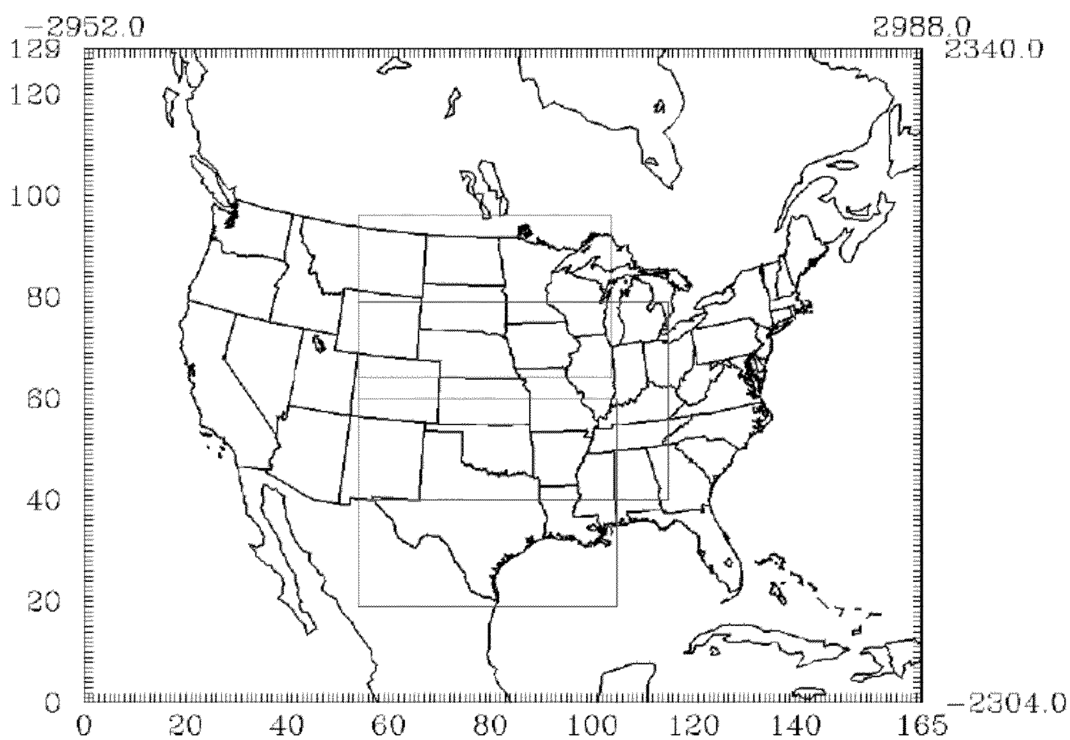
65 Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long-Range Transport and Impacts on Regional Visibility, EPA- 454/R-98-019, IWAQM, 1998; "Federal Land Managers' Air Quality Related Values Workgroup (FLAG)": Phase I Report, FLAG, USDI – National Park Service, Air Resources Division, Denver, CO., 2000. http://www.nature.nps.gov/air/Pubs/pdf/flag/FlagFinal.pdf;. EPA, 2003. "Revisions to the Guideline on Air Quality Models: Adoption of a Preferred Long Range Transport Model and Other Resources"; Final Rule. Fed. Reg./Vol. 68, No. 72/Tuesday April 15, 2003/Rules and Regulations. 40 CFR51.

(MING), Hercules-Glade Wilderness Area (HEGL), and Sipsey Wilderness Area (SIPS). These are the closest Class I areas to these facilities and each facility is within 300 km of at least one of these sites.

7.2.3 Modeling Domain and Meteorology Inputs

The CENRAP developed a set of three overlapping CALMET/CALPUFF modeling domains in the central United States covering the southern, central and northern portion of the CENRAP region (Fig. 7-1). The dimensions of the domain were selected to include the State of interest, plus Class I areas in nearby states, and to provide a sufficient buffer between the Class I areas and the domain boundaries (e.g., 50 km) to assure that CALPUFF puffs are not eliminated that may temporarily leave the domain and later reemerge and cause visibility impacts at a Class I area. The operator/owner may elect to restrict the computational CALPUFF domain to a subset of the CALMET domain to include the facilities of interest and only areas where significant impacts are feasible, extending at least 50 km in all directions beyond the class I areas within 300km of a source.

Figure 7-2. CENRAP CALMET 6km meteorological modeling domains



For BART screening analyses, CALPUFF modeling was performed by ADEQ consistent with the procedures described in section 6 of the CENRAP BART modeling guidance.[66] The CALMET modeling used terrain data from the Shuttle Radar Topography Mission (SRTM)-GTOPO 30 second (~1 km) resolution dataset and land use data from United States Geological Survey (USGS) Global Land Cover Characterization (GLCC) version 2.0 database at 30 second

[66]CENRAP BART Modeling Guidelines, Tesche, T. W., Dennis E. McNally, and George J. Schewe, Alpine Geophysics, LLC, 2005.

(~1km) resolution. CENRAP used MM5 meteorology data for the years 2001[67], 2002[68] and 2003[69] (at 36 km resolution to create 6-km resolution CALMET meteorological fields. Observational data was not blended with the MM5 data in the CALMET modeling, therefore sources were evaluated using the 1st High values instead of the 8th High values. The use of the 1st High modeling values was agreed to by EPA, representatives of the Federal Land Managers, and CENRAP stakeholders. EPA recommends performing three years of CALMET/CALPUFF modeling when using MM5 data and 2001 through 2003 were the most recent three years with MM5 data available at the time this modeling was initiated. The model-ready meteorological data sets for each domain were provided by CENRAP to expedite the screening analysis and provide for a consistent approach. To evaluate impacts at each Class I area, receptor data including coordinates and elevations that has been developed by the National Park Service.

7.2.4 Emissions Input

According to the EPA BART Guidelines: *"The emissions estimates used in the models are intended to reflect steady-state operating conditions during periods of high capacity utilization. We do not generally recommend that emissions reflecting periods of start-up, shutdown, and malfunction be used, as such emission rates could produce higher than normal effects than would be typical of most facilities. We recommend that States use the 24 hour average actual emission rate from the highest emitting day of the meteorological period modeled, unless this rate reflects periods start-up, shutdown, or malfunction."*[70]

The CENRAP BART modeling guidance recommends the following prioritization for identification of the maximum 24-hr actual emissions rates for the most recent 3 or 5 years, according to the following prioritization:

- Continuous Emissions Monitoring (CEM) data;
- Facility emissions tests;
- Emissions factors;
- Permit limits; or lastly,
- Potential to emit.

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[67] "Annual Application of MM5 for Calendar Year 2001". McNally, D. E., Alpine Geophysics, LLC, Arvada, CO. 178 pp., 2003 (http://www.epa.gov/scram001/reports/2001_36_mm5_summary_final.pdf); "Annual Meteorological Modeling Protocol: Annual Application of the MM5 to the Continental United States", McNally, D. E., and T. W. Tesche, 2002. (http://www.epa.gov/scram001/meteorology/metgridmodeling/annual_prot_1.1.pdf).
[68] Meteorological modeling protocol: IDNR 2002 annual MM5 application, Johnson, M. T., Iowa Department of Natural Resources, Air Quality Bureau, Des Moines, IA, 2003;. Iowa DNR 2002 Annual MM5 Modeling Project. Johnson, M. T., Presented at the August 11th, 2003 CENRAP Workgroup Meeting in Bloomington, Minnesota, 2003. (http://www.epa.gov/scram001/adhoc/johnson_2003.pdf)
[69] Baker, K., 2005. MM5 Model Performance: Great Lakes Region: 2002-04. *Ad-Hoc Meteorological Modelers Group Meeting*, Lakewood, Colorado. 11 June. (http://www.epa.gov/scram001/adhoc/baker_2005.pdf); Baker, K., M. Johnson, et al. 2005. Meteorological modeling performance summary for application to PM2.5/haze/ozone modeling projects, Prepared by the Lake Michigan Air Directors Consortium and the Midwest Regional Planning Organization, Des Plaines, IL.
(http://www.deq.state.va.us/export/sites/default/info/pdf/vchec/BoardBook/attachments/Attachment_8.pdf)
[70] EPA. 2005. "Regional Haze Regulations and Guidelines for Best Available Technology (BART) Determinations". Fed. Reg./Vol. 70, No. 128/Wed. July 6, 2005, Rules and Regulations, pp. 39104-39172. 40 CFR Part 51, FRL-7925-9, RIN AJ31.

Sources determined to be BART eligible were generally modeled using emission estimates based on the maximum 24 hour emission rates during the 2001-2003 meteorological period modeled. In-stack continuous emission monitoring (CEM) data were used where available.

For sources determined to be subject-to-BART, A five step BART analysis is required. Step 5 of the BART analysis (described in the BART guidelines[71]) requires an evaluation of the visibility impacts or degree of visibility improvement from the use of potential BART control technology. For this visibility analysis in support of a BART determination, the model should be run at the pre-control emission rates discussed above and the post-control emission rates determined from an evaluation of the control effectiveness of the available and technically feasible control technologies. The visibility improvement is assessed based on the modeled change in visibility impacts between the pre-control and post-control emission scenarios.

7.2.5 CALPUFF/CALMET Model Settings

The CALMET and CALPUFF model settings used by CENRAP and included in the CENRAP modeling protocol complied with our recommendations for regulatory application of the CALPUFF modeling system in effect at the time of the analysis with a few exceptions. Appendix A of the CENRAP BART modeling guidance details the CALMET settings used and the EPA default values, and Appendix B details the recommended CALPUFF settings used for screening analyses and the EPA default settings. Development of the regional CALMET meteorological fields from MM5 data for screening applications was conducted in No-Observations ("No-Obs") mode. Some of the differences between the CENRAP and EPA default CALMET modeling are detailed below.

i. The EPA default assumes no MM5 data will be used (IPROG=0). In the CENRAP BART screening analysis, MM5 data were used as an initial-guess field (IPROG=14);
ii. Gridded cloud data were inferred from the MM5 relative humidity fields (ICLOUD=3);
iii. CENRAP used the hourly 36-km MM5 data to define the upper-level winds, thus the extrapolation of the surface wind data aloft was not needed (IEXTRP= -1);
iv. The beginning and ending water land use categories were changed to 55, rather than using the EPA default (999) that assumes no water land use categories.

ADEQ's modeling used a constant value of 3 ppb background concentration of ammonia for the domain during the modeling period. Hourly ozone observational data provided by ADEQ over the 2001-2003 timeframe were used to define background ozone concentrations.

7.3 BART DETERMINATIONS

The third step of a BART evaluation is to perform the BART analysis. The BART Guidelines describe the BART analysis as consisting of the following five basic steps:

- Step 1: Identify All Available Retrofit Control Technologies,

[71] 70 FR 39164.

- Step 2: Eliminate Technically Infeasible Options,
- Step 3: Evaluate Control Effectiveness of Remaining Control Technologies,
- Step 4: Evaluate Impacts and Document the Results, and
- Step 5: Evaluate Visibility Impacts.

The BART analysis includes engineering and modeling methods and procedures used to determine the appropriate controls for the subject-to-BART units to reduce the source's contribution to pollutant concentrations that result in visibility impairment in the surrounding Class I areas. The final factor to consider under EPA's BART Guidelines is the degree of visibility improvement from the BART control options[72]. The BART guidelines recommend use of the CALPUFF air quality dispersion model to estimate the visibility improvements at each Class I area, typically within roughly a 300 km (186 mile) or larger radius of the source, of alternative control technologies, and to compare these to each other and to the impact of the baseline, or current, source configuration.

The subject-to-BART facilities conducted modeling or relied on ADEQ post-control modeling that followed the ADEQ modeling protocol. The modeling analyses generally followed the BART modeling protocol developed by CENRAP. AECC (Bailey and McClellan)[73] and AEP Flint Creek[74] relied on post-control modeling performed by ADEQ. Domtar contracted with Trinity consultants to perform the BART analysis for this facility. Trinity consultants utilized ADEQ modeling files, adjusting only the emission rates to be modeled for their post-control modeling scenario.[75] Entergy Lake Catherine and Entergy White Bluff BART analyses were performed by ENSR Corporation and were conducted in a manner generally consistent with the ADEQ approach, but did deviate in some ways by using a different CALPUFF version and used the 98th percentile (8th highest day) in this analysis instead of the maximum visibility impact.[76] The BART analyses conducted by each facility for subject-to-BART sources are included in Appendix 9.3A of the AR RH SIP. As described below, we have identified several problems with the BART analyses performed by ADEQ.

7.3.1 Issues identified with ADEQ BART analyses.

ADEQ made BART determinations for the subject-to-BART sources for NOx, SO_2, and PM (when we discuss PM we are referring to primary PM and not secondary). We have found several problems in these BART analyses, which lead us to propose disapproval of some of ADEQ's BART determinations. These problems are discussed in detail in our proposed action and in the accompanying TSD. Some general issues with the visibility impact modeling are summarized below as well as a discussion of the visibility analysis performed for each source.

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[72] 59 FR 39104, 39170 (July 6, 2005).
[73] Arkansas Electric Cooperative Corporation Best Available Retrofit Technology Engineering Analysis prepared by Stephen Cain, October 20, 2006
[74] Letter from Southern Electric Power Company (SWPECO, T. Brian Bond) to ADEQ (Mike Bates), October 26, 2006
[75] Best Available Retrofit Technology Determination, Domtar Industries, Inc., Ashdown Mill, Prepared by Trinity Consultants, Revised March 26, 2007
[76] BART Analysis for the White Bluff Steam Electric Station, ENSR Corporation, December 2006; BART Analysis for Lake Catherine Plant-Unit 4, ENSR Corporation, December 2006

7.3.1.1 Use of Pollutant-specific modeling

Pollutant specific modeling was performed by ADEQ for those sources subject-to-BART. The results of this modeling was used to determine which pollutants (NOx, SO_2, and/or PM) are impacting visibility. For some sources, a BART visibility analysis and evaluation of controls for one or more pollutants was not performed based on the assumption that if pre-control modeling conducted on the basis of a single pollutant showed that the source's emissions of the pollutant in question did not "contribute" to visibility impairment then further BART analysis for that pollutant was unnecessary. This approach is unacceptable. Due to the nonlinear nature and complexity of atmospheric chemistry and chemical transformation among pollutants, all relevant pollutants should be modeled together to predict the total visibility impact at each Class I area receptor. [77] NOx and SO2 emissions should be modeled together to determine the visibility impacts attributable to these pollutants and in evaluation of controls and combinations of controls in determining BART for a source.

Predicting the impacts of PM on visibility is relatively straight-forward, unlike predicting the impacts of SO2 and NOx. Using CALPUFF on a pollutant specific basis to model only the impact of PM emissions on visibility may be an acceptable approach to determine whether a source should be subject to review for PM controls, or alternatively, that the source is not subject to BART for PM. ADEQ applied a threshold of 0.5 dv for determining whether a source "contributes" to visibility impairment on a per-pollutant basis. As discussed above, the State selected a threshold of 0.5 dv for the initial screening modeling that included all pollutants. Clearly, a lower threshold value is needed in evaluating pollutant-specific modeling for sources that emit more than one visibility impairing pollutant. Furthermore, this approach is only acceptable for PM-specific modeling. We note that a State may establish de minimis levels of emissions (applicable on a plant-wide basis) of visibility impairing pollutants to exclude some sources from further evaluation when the emissions are so minimal that they are unlikely to contribute to regional haze.

7.3.1.2 Adoption of Presumptive Limits

For some facilities a BART visibility analysis was not performed, and instead the presumptive limits found in the BART Guidelines were adopted. This approach is unacceptable. We note that the BART Rule does not suggest the presumptive limits should be viewed as establishing a safe harbor from more stringent regulation under the BART provisions, and adoption of the presumptive limits does not exempt a source from doing a BART five factor analysis. Only when a source has controls already in place that are the most stringent controls available, or when a source commits to a BART determination that consists of the most stringent controls available, can the source forego a BART five factor analysis, including a visibility analysis of the anticipated visibility benefits due to the use of available and technically feasible controls.

7.3.1.3 Selection of post-control scenarios to model

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[77] Memo from Joseph Paisie (Geographic Strategies Group, OAQPS) to Kay Prince (Branch Chief EPA Region 4) on Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations, July 19, 2006

For the BART determinations for which a BART visibility analysis was performed, the determination of the control technologies and the control efficiencies to model was inadequate. Source-specific BART modeling performed to determine the visibility improvement that would result from installation of controls failed to properly take into consideration the technology available and/or the maximum level of control each control option is capable of achieving. As part of the BART analysis, the facility must evaluate the visibility impacts of all technically feasible control options considered before making a BART determination. In most cases, the facility made a BART determination without evaluating the visibility improvement anticipated due to the use of all technically feasible control options and performed visibility modeling only after a control technology was selected as BART. This approach is unacceptable and does not allow for a comparison of the effectiveness of available controls in reducing visibility impacts to be considered as part of the BART determination.

7.3.2 ADEQ BART Results and Summary

We have reviewed ADEQ's BART determinations for the sources listed in Table 7-3, above. For the reasons above and as discussed in more detail in the proposed rulemaking and TSD, we are proposing to find that ADEQ has partially satisfied the BART requirement of section 51.308(e). We are proposing to find that the BART determinations listed in Table 7-4 do not satisfy the BART requirement of section 51.308(e). We are proposing to find that the BART determinations listed in Table 7-5 and discussed below satisfy the BART requirement of section 51.308(e). We are also proposing to find that Georgia-Pacific Crossett Mills is subject-to-BART and requires a full BART analysis to satisfy the BART requirement of section 51.308(e).

Table 7-4. BART Determinations Not Satisfying Section 51.308(e)

Facility Name	BART Emission Unit	Pollutant	BART emission limit[78]
Arkansas Electric Cooperative Corporation Carl E. Bailey Generating Station	Unit 1	SO_2	Use of fuel oil with 1% sulfur content
		NOx	No BART Determination
		PM	No BART Determination
Arkansas Electric Cooperative Corporation John L. McClellan Generating Station	Unit 1	SO_2	Use of fuel oil with 1% sulfur content
		NOx	No BART Determination
		PM	No BART Determination
American Electric	Boiler No. 1	SO_2	0.15 lb/MMBtu

[78] Emission limits are based on a 30-day rolling average.

Facility Name	BART Emission Unit	Pollutant		BART emission limit[78]
Power Flint Creek Power Plant		NOx		0.23 lb/MMBtu
Entergy Lake Catherine Plant	Unit 4	natural gas firing	NOx	0.15 lb/MMBtu
		fuel oil firing	SO2	0.562 lb/MMBtu
			NOx	0.25 lb/MMBtu
			PM	0.037 lb/MMBtu
Entergy White Bluff Plant	Unit 1	bituminous coal firing	SO_2	0.15 lb/MMBtu
			NOx	0.28 lb/MMBtu
		sub-bituminous coal firing	SO_2	0.15 lb/MMBtu
			NOx	0.15 lb/MMBtu
	Unit 2	bituminous coal firing	SO_2	0.15 lb/MMBtu
			NOx	0.28 lb/MMBtu
		sub-bituminous coal firing	SO_2	0.15 lb/MMBtu
			NOx	0.15 lb/MMBtu
	Auxiliary Boiler	All		Boiler to be operated no more than 4360 hrs annually
Domtar Ashdown Mill	No. 1 Power Boiler	SO_2		1.12 lb/MMBtu
		NOx		0.46 lb/MMBtu
	No. 2 Power Boiler	SO_2		1.20 lb/MMBtu
		NOx		0.45 lb/MMBtu
		PM_{10}		0.10 lb/MMBtu

Table 7-5. BART Determinations Satisfying Section 51.308(e)

Facility Name	BART Emission Unit	Pollutant		BART emission limit[79]
American Electric Power Flint Creek Power Plant	Boiler No. 1	PM_{10}		0.10 lb/MMBtu
Entergy Lake Catherine Plant	Unit 4	natural gas firing	SO_2	No BART Determination
			PM_{10}	existing PM emission limit (45 lb/hr)
Entergy White Bluff Plant	Unit 1	bituminous coal firing	PM_{10}	existing PM emission limit (0.10 lb/MMBtu)
		sub-bituminous coal firing	PM_{10}	existing PM emission limit (0.10 lb/MMBtu)
	Unit 2	bituminous coal firing	PM_{10}	existing PM emission limit (0.10 lb/MMBtu)
		sub-bituminous coal firing	PM_{10}	existing PM emission limit (0.10 lb/MMBtu)
Domtar Ashdown Mill	No. 1 Power Boiler	PM_{10}		0.07 lb/MMBtu

7.3.2.1 PM BART for AEP Flint Creek No. 1 Boiler

ADEQ conducted pre-control CALFUFF modeling for the AEP Flint Creek No. 1 Boiler showing that PM_{10} and $PM_{2.5}$ emissions from the source have minimal visibility impacts at each Class I area within 300 km. Therefore, ADEQ determined that the existing PM emission limit in the operating air permit achievable through the use of the existing electrostatic precipitator (ESP) is BART for PM for AEP Flint Creek No. 1 Boiler. We reviewed the CALPUFF visibility modeling submitted by ADEQ for AEP Flint Creek No. 1 Boiler, and agree that PM_{10} and $PM_{2.5}$ emissions from the source have minimal visibility impacts at each Class I area within 300 km. Table 7-6 shows the percent contribution to visibility impacts due to PM for the 1st High days. Less impacted days (8th High) show similar contributions from PM. We have found that the visibility impact due to PM emissions alone is so minimal such that the installation of any additional PM controls on the unit would likely achieve very low emissions reductions, have minimal visibility benefit, and not be cost-effective. Therefore, we propose to approve ADEQ's determination that PM BART for AEP Flint Creek No. 1 Boiler is the existing PM emission

[79] Emission limits are based on a 30-day rolling average.

limit. ADEQ did not specify in the RH SIP what the existing PM emission limit for the source is, but the current operating air permit for the source indicates the PM emission limit for the unit is 0.1 lb/MMBtu

Table 7-6. Percent contribution of PM (course and fine) to total visibility impairment on 1st High day. ADEQ pre-control screening modeling (Appendix 9.2B), AEP-Flint Creek

	CACR		HEGL		MINGO		SIPS		UPBU	
	%_PMC	%PMF	%_PMC	%PMF	%_PMC	%PMF	%_PMC	%PMF	%_PMC	%PMF
2001	0.06	0.16	0.23	0.14	0.03	0.15	0.03	0.09	1.33	0.65
2002	0.16	0.18	0.29	0.17	0.08	0.13	0.01	0.08	0.24	0.18
2003	0.06	0.11	0.15	0.15	0.02	0.1	0.03	0.09	1.25	0.62

7.3.2.2 SO2 and PM BART for natural gas firing scenario for Entergy Lake Catherine Unit 4

Since Unit 4 is permitted to burn both natural gas and No. 6 fuel oil, ADEQ made BART determinations for both natural gas firing and fuel oil firing scenarios. The Arkansas RH SIP contains the CALPUFF pre-control modeling files for the natural gas firing scenario. SO_2 and PM emissions from natural gas-fired boilers are generally very low. We agree with ADEQ's decision not to make a BART determination for SO_2 for the natural gas firing scenario for Unit 4. Revisions to the State's RH Rule, Chapter 15 of APC&E Commission Regulation 19, which were submitted to us on August 3, 2010, state the existing PM emission limit as of October 15, 2007 is PM BART for the natural gas firing scenario for Entergy Lake Catherine Unit 4. This corresponds to an emission limit of 45 lb/hr PM. Since we have found that the visibility impact due to PM emissions alone is so minimal such that the installation of any additional PM controls on the unit would likely achieve very low emissions reductions, have minimal visibility benefits, and not be cost-effective, we are also proposing to approve ADEQ's determination that BART for PM is the existing PM emission limit as of October 15, 2007, or 45.0 lb/hr, for the natural gas firing scenario for Unit 4.

7.3.2.3 PM BART for Units 1 and 2 Entergy White Bluff

ADEQ's determined that most of the visibility-causing emissions from Units 1 and 2 are due to SO_2 and NOx, and determined that PM_{10} emissions are well-controlled with existing electrostatic precipitators (ESPs). We reviewed the pre-control screening CALPUFF visibility modeling submitted by ADEQ for Entergy White Bluff, and agree that PM emissions from the source have minimal visibility impacts at each Class I area within 300 km. Table 7-7 shows the percent contribution to visibility impacts due to PM for the 1st High days. Less impacted days (8th High) show similar contributions from PM. We have found that the visibility impact due to PM emissions alone is so minimal such that the installation of any additional PM controls on the unit would likely achieve very low emissions reductions, have minimal visibility benefit, and not be cost-effective. We propose to approve ADEQ's determination that PM BART for both the bituminous and sub-bituminous coal firing scenarios is the existing PM emission limit for Units 1 and 2. The operating air permit states the PM emissions from the two units are controlled with ESPs and requires that the two units comply with a PM emission standard of 0.10 lb/MMBtu.

Table 7-7. Percent contribution of PM (course and fine) to total visibility impairment on 1st High day. ADEQ pre-control screening modeling (Appendix 9.2B), Entergy White Bluffs

	CACR		HEGL		MINGO		SIPS		UPBU	
	%_PMC	%PMF	%_PMC	%PMF	%_PMC	%PMF	%_PMC	%PMF	%_PMC	%PMF
2001	0.11	0.27	0.04	0.3	0.03	0.16	0.03	0.16	0.05	0.21
2002	0.04	0.17	0.04	0.17	0.06	0.32	0.03	0.14	0.05	0.19
2003	0.04	0.21	0.09	0.26	0.06	0.26	0.08	0.21	0.04	0.17

7.3.2.4 PM BART for Domtar Power Boiler No. 1

ADEQ stated the Domtar No. 1 Power Boiler was at the time subject to the Boiler Maximum Achievable Control Technology (MACT) [80] PM emission standard of 0.07 lb/MMBtu. A wet ESP was installed at the No. 1 Power Boiler to meet the 0.07 lb/MMBtu Boiler MACT PM emission standard. The BART guidelines state that for PM sources subject to MACT standards, States may streamline the analysis by including a discussion of the MACT controls and whether any major new technologies have been developed subsequent to the MACT standards. Concerning Power Boiler No. 1, ADEQ provided a discussion of other PM control technologies available at the time, and determined that a wet ESP with a PM emission limit of 0.07 lb/MMBtu on a 30-day rolling average is BART for Power Boiler No. 1. We agree that ADEQ's streamlined approach and determination for BART for PM for Power Boiler No. 1 is consistent with the BART Guidelines and propose to approve it.

[80] The MACT standards are part of the National Emission Standards for Hazardous Air Pollutants for Source Categories (NESHAP), provided under 40 CFR 63.